United States
Department of
Agriculture

Forest Service

General Technical
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CONTENTS

INTRODUCTION

Overview of the Ozone Indicator

Ozone interacts with forest ecosystems, causing visible injury and alterations in species composition and pest interactions (Chappelka and Samuelson 1998, Miller and others 1996). It is the only regional gaseous air pollutant that has been measured at known phytotoxic levels at both remote and urbanized forest locations (U.S. EPA 1996a,b). The importance of ozone as a forest stressor is illustrated by its inclusion in the Montréal Process Criteria and Indicators (Montreal Process 1995) in which the percent forest exhibiting negative impacts from air pollutants such as ozone is an indicator of the overall forest health and vitality. Coulston and others (2004) point out that the ozone biomonitoring data of the USDA Forest Service Forest Inventory and Analysis Program (FIA) are the only source of information available that documents plant injury from air pollution using consistent protocols. The goal of our document is to describe the ozone bioindicator and suggest analytical techniques appropriate for FIA ozone biomonitoring data.

The ozone bioindicator provides a biological index of ozone stress to plants using consistent protocols on a nationwide system of biomonitoring sites. Ozone biomonitoring is part of the FIA phase 3 sample (USDA Forest Service 2005) and is based on the documentation of visible foliar injury to known ozone-sensitive plant species under conditions of ambient exposure. The field methods, site variables, and site-level biovag(o)0(r)of am,pn5i10(e)0(fdN5Cpeconsist1TJn2(ndicato(5) .8(t of Dp impor)-

Detection Monitoring

The FIA ozone biomonitoring program is designed to detect and monitor plant-damaging concentrations of ozone in the natural environment. Information gathered at ozone biomonitoring sites identifies whether conditions exist (ozone, light, moisture, relative humidity) for plant injury to occur. This information can be used to report national and regional trends in ozone injury to plants and to identify areas of concern for closer evaluation. The biomonitoring grid is independent of the sampling grid and an analysis of air quality and environmental data that influence plant response to ozone. It may also be important to examine species distribution maps available from FIA regional archives. An example of DM identifying a potential problem area and EM verifying the problem is illustrated by Coulston and others (2003) and Skelly and others (2003), respectively.

Key References

Biosite index: The Horsfall-Barrett (HB) rating scale used to assess ozone injury in the field is based on a technique developed for plant disease research. Since the 1940s, it has been used repeatedly in the field evaluation of ozone-induced foliar injury. Details on the formulation of the site-level biosite index (BI) are presented in Biosite Index and Proportion Injured Plants, page 6. The index developed for the FIA program is new, but it has been widely adopted by cooperating researchers at various institutions and published in the scientific literature.

Key references: Horsfall and Barrett 1945, Horsfall and Cowling 1978, Smith and others 2003.

Classification scheme for the biosite index: The classification scheme for the FIA biosite index has been reviewed in the scientific literature and applied in a published assessment of ozone injury to eastern forest tree species.

Key references: Coulston and others 2003, Smith and others 2003.

Interpolation techniques: Plot-level attributes required for population estimates are developed by spatial interpolation of the biosite data. Spatial interpolation techniques are widely used in the analysis of air pollution, environmental, and ecological data. The approach used for the ozone indicator has been reviewed in the scientific literature and applied in a published assessment of ozone injury to eastern forest tree species.

Key references: Coulston and others 2003, Cressie 1993, Cressie and Ver Hoff 1993, Isaaks and Srivastava 1989, Lefohn and Pinkerton 1988.

Status and change estimation: There are several references for valid estimation techniques; however, Bechtold and Patterson (2005) provide a review and recommendations specifically for FIA data.

Key reference: Bechtold and Patterson (2005)

The sampling rules for the ozone biosites are as follows. Biosites are wide-open areas, at least one acre in size, within or alongside forested areas. Each site must contain at least 30 individual plants of at least two bioindicator species. If not enough plants are available at one location, two nearby open areas, within 3 miles of each other, may be combined to maximize plant counts. Biosite locations must be easy to access, and they must be free of significant soil compaction and other human-made disturbance. Additional guidelines are available in the Field Methods Guide (USDA Forest Service 2000).

The characteristics of each site are described in terms of the size of the open area, elevation, terrain position, aspect, soil drainage, soil depth, and site disturbance. If characteristics vary significantly across the biosite, then the area where most of the bioindicator species are growing is described and variations are recorded on the site map and notes. When two nearby open areas are used, each location is described separately.

Up to 30 plants of each species are randomly selected for injury evaluation. Plants less than 12 inches in height, suppressed, shaded, or with more than half the crown out of reach are not evaluated. The approximate locations of the plants used for evaluations are drawn on the site map so that the same population of plants is evaluated on return visits to the biosite. The entire open area is sampled until 30 plants of two (ideally, three or more) species have been evaluated.

Quality assurance (QA) procedures dictate that the ozone injury symptom must be verified for each injured species on each site. Crews collect a minimum of three injured leaves from a random sample of individual plants that show obvious ozone injury, and they mail pressed leaf samples to a regional expert for review. Three leaves from each injured species are subject to microscopic examination. Injury is validated for all samples that show a characteristic color and injury pattern for ozone and that are otherwise free of confounding signs and symptoms of other mimicking stress agents (e.g., insects, disease, mites, or weather). If the symptoms are not typical of ozone injury, then the field data associated with the invalidated leaf voucher are zeroed out. Furthermore, if a leaf voucher is missing and unable to be validated, then the field data associated with the missing voucher are flagged so they cannot be used in data summaries or analyses.

The ozone indicator is included in the FIA National QA Plan (USDA Forest Service 2004). Just before the sampling window, ozone training and certification sessions are held in each region. A minimum of 10 biosites per region are blind checked every year (5 to 6 percent of the total biosites in each region). The ozone remeasurement data have been evaluated on two occasions, once in 1999 and again in 2003 (Pollard and Smith 2001, Pollard 2004). Inconsistent results with two eastern bioindicator species reported in Pollard and Smith (2001) were corrected by improvements to the ozone training session. Results from the 2003 review indicate the biosite data are robust and field crews in all regions are able to meet data quality expectations for the ozone indicator.

POINT-IN-TIME ESTIMATION

Plant-level Estimates

At each ozone biosite, 30 individual plants of two bioindicator species and between 10 and 30 individual plants of additional bioindicator species are evaluated for ozone injury. Each plant is rated for the proportion of leaves with ozone injury (injury amount) and the mean severity of symptoms (injury severity) using a modifi percent (Horsfall and Cowling 1978, USDA Forest Service 1999). This scale uses class break points that correspond to the ability of the human eye to distinguish gradations of healthy and unhealthy leaf tissue.

Biosite Index and Proportion Injured Plants

For each biosite, the percent injured plants and a biosite index are calculated based on the injury amount and severity scores. The proportion injured is $Ip=n_i/n_t$ where Ip is the proportion of plants injured, n_i is the number of injured plants (i.e., amount of injury ≠ 0), n_t=the total number of plants evaluated. The biosite index is the average score (amount ∗ severity) for each species averaged across all species on the biosite multiplied by 1,000 to allow risk categories to be defined by integers (Table 1). The biosite index is calculated

$$BI = 1000\left[m^{-1} \sum_{j=1}^{m} n_j^{-1} \sum_{p=1}^{n_j} a_{pj} s_{pj} \right]$$

where

BI = biosite index

m = number of species evaluated

n_j =number of plants of the j^{th} species evaluated

a_{pj} =proportion of injured leaves on the p^{th} plant of the j^{th} species

s_{pj} =average severity of injury on the p^{th} plant of the j^{th} species

Biosite summary statistics on the ozone indicator are generated annually and loaded to three ozone data summary tables in each FIA region. Tabular data include species and site counts and calculated mean injury indices from the first year each state implemented the ozone indicator up to the current year. For some regions it is important to group states with similar air quality regimes together and keep them separate from neighboring states with distinctly different air quality regimes. A map of biosite-level values will also be produced for illustration. Tables and figures illustrating these types of products are included in Appendix I.

Status Estimation

FIA plot-level attributes required for population estimates can be developed by spatial interpolation of data collected from the biosites. Each ozone season is unique, influenced by variable ozone levels, weather, windflow, and precipitation patterns. Therefore, it is important to use 5-year averages of the biosite index to generate a truly representative estimate of ozone stress. Thus, a 5-year moving average is used:

$$\hat{B}_t = \sum_{t=-(n-1)}^{0} \frac{B_t}{n}$$

Cross-validation is a method to quantify and compare various models (e.g., kriging and IDW). It can also be used to decide among variogram models (e.g., spherical, Gaussian). The cross-validation technique is implemented sequentially by removing each v_i one at a time and then estimating v_i based on the spatial model (e.g., IDW) and the remaining *n*-1 observations. If this is done sequentially for all *i* =1,.,.,.,*n* observations in the sample, the estimates can then be compared to the actual values using several standard summary statistics (Prediction error sum of squares – PRESS statistics).

The PRESS statistics are the values analysts may use to decide on which interpolation model performs the best for their particular situation. One PRESS statistic is the average squared deviation $= n^{+1} \acute{U}_{i} (v_i + \hat{v}_{+i})^2$ where $\hat{v}_{+i}$ is the prediction of v_i from the rest of the data. This value should be relatively small if the model fits well. Another summary statistic is the mean of standardized PRESS residuals $= n^{+1} \acute{U}_{i} (v_i + \hat{v}_{+i}) / \sqrt{S_{(+i)}{}^2}$ where $S_{(+i)}{}^2$ is the estimation variance for $\hat{v}_{+i}$. This quantity should be close to zero if the model fits well. The root mean squared prediction residuals also provide a measure of model aptness. This is calculated by $\sqrt{n^{+1} \acute{U}_{i} \left(v_i + \hat{v}_{+i} / \sqrt{S_{(+i)}{}^2}\right)^2}$ and will be approximately one if the spatial model fits well. An analyst should create several interpolated maps using the various options for the IDW and kriging. For example, analysts may choose to create an IDW map based on the 12 nearest neighbors rather than all neighbors. Analysts may also decide to try several variogram models (e.g., spherical, Gaussian) with the kriging technique. The resultant maps can then be compared based on the PRESS statistics, and the analysts can decide on the most appropriate map.

Once an appropriate spatial model has been selected, biosite index values will be estimated for all P2 and P3 plots by intersecting the map of interpolated values with P2 and P3 plot locations (e.g., Fig. 2). This will result in a biosite index value estimate for each P2 and P3 plot (e.g., Table 2).

E S F A

Bioindicator attributes will be estimated yearly for all FIA plots, using the procedures described above. The attributes will then be merged with the other plot attributes. Population estimates include (1) the proportion of forest land in each biosite index category by region, ecoregion, and state; (2) the acres of forest land in each biosite index category by region, ecoregion, and state; and (3) the volume of ozone-susceptible species in each biosite index category by region, ecoregion, and state. Population estimates will be made using the procedures presented by Bechtold and Patterson (2005).

a_{mhijk} = mapped area (acres) of subplot (macroplot) j covering condition k on plot i assigned to stratum h. (Area is computed using the largest area mapped, which is the subplot except in the Pacific Northwest (PNW) where the macroplot or 1-ha circle is used.)
δ_{hijkd} = zero-one domain indicator function, which is 1 if condition k on subplot (macroplot) j of plot i assigned to stratum h belongs to the domain of interest d
K_{hij} = the number of conditions that exist on subplot (macroplot) j of plot i assigned to stratum h
a_m = total area of the largest plot on which area attributes are mapped (i.e., four times the subplot or macroplot area)
$\bar{p}_{mh}$ = mean proportion of stratum h mapped plot areas falling within the population ($\bar{p}_{mh}$ is generally 1 unless the plot is partially outside the population. If this situation arises, see Bechtold and Patterson (2005)).

The estimated proportion of forest land in strata h and domain d is simply the average of the plot values.

$$\overline{P_{hd}} = \frac{\sum_{i}^{n_h} P_{hid}}{n_h}$$

The total area in the domain of interest is then

$$\hat{A}_d = A_T \sum_{h}^{H} W_h \overline{P_{hd}} = A_T \overline{P_d} \quad \text{where}$$

A_T = total area in the population in acres
$\bar{P}_d$ = estimated proportion of the population in the domain of interest d
W

These values are then averaged across each *i* plot

$$\overline{Y_{hd}} = \frac{\sum_{i}^{n_h} y_{hid}}{n_h}$$

The total for the attribute of interest in the domain of interest is then

$$\hat{Y}_d = A_T \sum_{h}^{H} W_h \overline{Y_{hd}} = A_T \overline{Y_d}$$

See Output Tables and Maps section for example output.

DISCUSSION

Here we present one method to perform DM by classifying each FIA plot based on an interpolated map of ozone injury risk. The purpose of this activity is to identify candidate areas for EM. As with other DM activities, there is a high noise to signal ratio and there may be a relatively high rate of false positives. For this reason, EM is an essential part of the process. The map of ozone injury risk does have unquantified error. However, other maps used to classify FIA plots (e.g., ecoregion sections, counties) also have unquantified error. When the information is used at its intended resolution, unquantified errors may be overlooked. For the ozone bioindicator, error propagation can be overlooked for DM activities. However, error propagation cannot be overlooked if one is trying to make a statistical inference about the relationship between growth rates and ozone injury.

The purpose of this document is to describe the analytical techniques used with the ozone indicator. We provided background material on ozone, examples of biosite summary statistics, a description of spatial interpolation, and methods to estimate status and change in forested areas with respect to the occurrence of ozone injury from ambient ozone concentrations. Appendix I includes examples of each

REFERENCES

Bechtold, W.A.; Patterson, P.L., eds. 2005.

Feder, W.A. 1978. **P** **.**
Environmental Health Perspectives. 27: 139-147.

Gillespie, A.J.R. 1999. **R** **.** Journal of Forestry. 97: 16-20.

Heck, W.W. 1968. **F** **.** Annual Review of Phytopathology. 6: 165-187.

Hildebrand, E.S.; Skelly, J.M.; Federickson, T. 1996. **I** **-** **1991-1993** **S** **N** **P ,** **.** Canadian Journal of Forest Research. 26: 658-659.

Hoeting, J.A.; Davis, R.A.; Merton, A.A.; Thompson, S.E. 2006. **M** **.** Ecological Applications. 16(1): 87-98.

Horsfall, J.G.; Barrett, R.W. 1945. **A** **.** Phytopathology. 35: 655.

Horsfall, J.G.; Cowling, E.B., eds. 1978. **P** **:** **.** In: Plant disease. New York: Academic Press: 119-136. Vol. II.

Isaaks, E.H.; Srivastava, R.M. 1989. **A** **.** New York: Oxford University Press. 561 p.

Kohut, R.; Laurence, J.; King, P.; Raba, R. 1997. **I** **A** **N** **P** **.** On file with: U.S. Department of the Interior, National Park Service, P.O. Box 25287, Denver, CO 80225-0287.

Krupa, S.V.; Manning, W.J. 1988. **A** **:** **.** Environmental Pollution. 50: 01-137.

Krupa, S.V.; Tonneijck, A.E.G.; Manning, W.J. 1998. **O** **.** In: Flager, R.B. ed. Recognition of air pollution injury to vegetation: a pictorial atlas. Pittsburgh, PA: Air & Waste Management Association: sec. 2.1-2.23.

Lefohn, A.S.; Pinkerton, J.E. 1988. **H** **S** **.** JAPCA. 38: 1504-1511.

P . PSIE 2003-5. University Park, PA: Pennsylvania State University Institute of the Environment.

Smith, G.C. 1995. **FHM - .** Unpublished report. On file with: USDA Forest Service, Forest Health Monitoring Program, Research Triangle Park, NC 27709.

Smith, G.C.; Coulston, J.W.; Jepsen, E.; Prichard, T. 2003. **A (1994 - 2000).** Environmental Monitoring and Assessment. 87: 271-291.

Smith, G.C.; Coulston, J.W.; O'Connell, B. In review. **O : , , F I A P .**

Smith, W.D.; Coulston, J.W.; Smith, G.C. 2001. **D .** Unpublished report. On file with: USDA Forest Service, Forest Inventory and Analysis Program, Research Triangle Park, NC 27709.

Smith, W.H. 1981. **F : .** In: DeSanto, R.S., ed. Air pollution and forests, interactions between air contaminants and forest ecosystems. New York: Springer-Verlag. 379 p.

Temple, P.J. 2000. **O S , F .** On file with: USDA Forest Service, Forest Health Monitoring Program, Research Triangle Park, NC 27709.

USDA Forest Service. 1999. **F H M 1999 F M G .** USDA Forest Service, National Forest Health Monitoring Program. Research Triangle Park, NC 27709.

USDA Forest Service. 2000. **F I A , N C F G : F P 2 & 3 P O .** U.S. Department of Agriculture, Forest Service, Northeastern Research Station, Newtown Square, PA, and Pacific Northwest Research Station, Portland, OR. Vol. 1, Sec. 9.0.

USDA Forest Service. 2004. **F I A , P C Q A I P , 1.0.** Internal report. On file with: U.S. Department of Agriculture, Forest Service, 201 14th St., Washington, DC 20250.

USDA Forest Service. 2005. **P 2 P 3: G M .** FIA Fact Sheet Series. http://fia.fs.fed.us/library/fact-sheets/data-collections/Phase2_3.pdf.

U.S. Department of the Interior. National Park Service Air Resources Division. U.S. Fish and Wildlife Service Air Quality Branch. Denver, CO. November 2003. NPS D1522. Natural Resources Report NPS/NRARD/NRR-2003/01. **O N**

P S .S. F L : J 24-25, 2003 . Baltimore, MD. Available at: http://www2.nature.nps.gov/air/studies/ecoOzone.cfm.

U.S. Environmental Protection Agency. 1996a. **A .** Environmental concentrations, patterns, and exposure estimates. EPA/600/P-93/004aF. Washington, DC: Office of Research and Development. Vol.1, Sec. 4.

U.S. Environmental Protection Agency. 1996b. **A .** Environmental effects of ozone and related photochemical oxidants, EPA/600/P-93/004aF. Washington, DC: Office of Research and Development. Vol. II, Sec .5.

Vose, D. 2000. **R : .**

APPENDICES

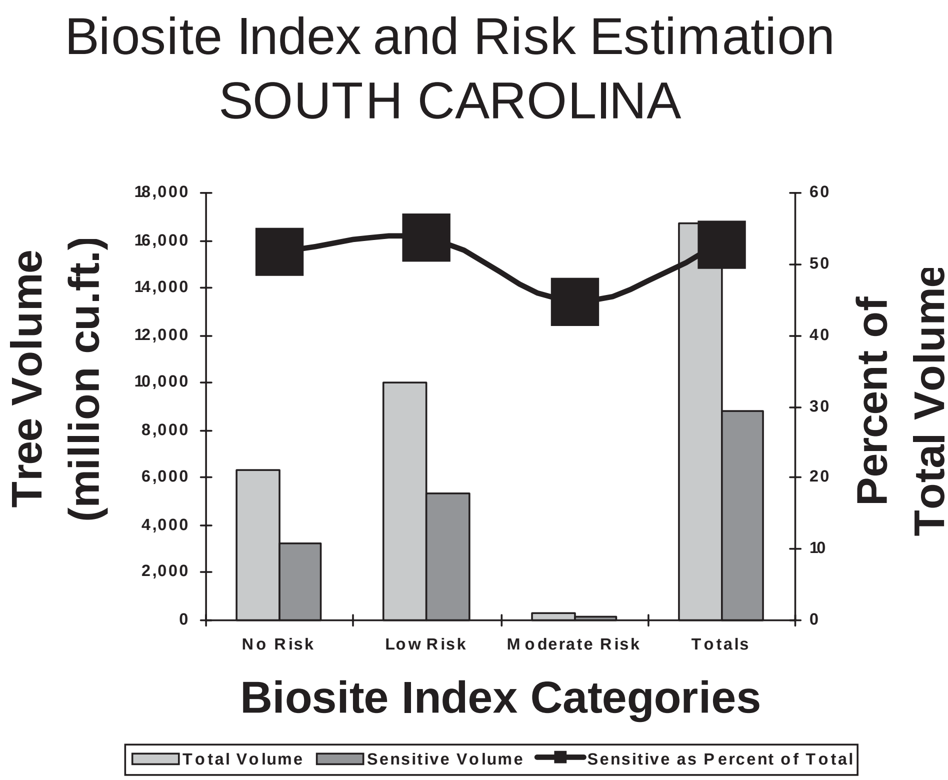
The appendices include supplementary information on the ozone indicator. Appendix I, Output Tables and Maps, includes examples of output tables and maps suitable for FIA state reports. Appendix II, Ozone Sensitivity of Tree and Shrub Species, includes ozone sensitivity tables for trees and shrubs, information that is needed for risk assessment analysis, and Appendix III, Documents for Ozone Information Management, provides information on ozone data in the FIA national information management system (NIMS) and FIA public database (FIADB), as well as contact information for individuals most familiar with the ozone biomonitoring program in FIA.

Appendix I: Examples of Output Tables and Maps for Annual and Multiyear Summary Reports

Note: Tables 3 and 4 provide an example of site-level summary statistics from State X and Region ABC. These two tables are core products for the ozone indicator. The summarized values show the base data used to generate the plot-level and population-level estimates as described in the text of this document. Individual states may choose to use the regional table as a basis of comparison to their summary statistics. Smaller states may choose to use the regional table for reports.

Note: This map of ozone risk to plants is a core product for the ozone indicator. In this example, biosite index values were averaged across the 4-year sampling period from 1999 to 2002 and then geostatistical procedures were used to create an interpolated bioindicator response surface across the landscape (see Status Estimation, page 6). The interpolated data are classified into color-based gradations of response representing low risk of probable ozone injury to forests (green), moderate risk (yellow), and high risk (red). These categories also provide an indication of ozone relative air quality with respect to a plant receptor (see Table 1). Intensified sampling is recommended where high ozone stress coincides with the spatial distribution of ozone-sensitive tree species. Refer to Appendix II for more information on the ozone sensitivity of tree species.

The ozone risk map is used to estimate bioindicator attributes for all FIA plots using the procedures described in the section on Spatial Interpolation of the Bioside Index, page 7. BI attributes are merged with other FIA plot attributes to generate population estimates using the procedures described in the section on Estimating Status for Forested Areas, page 8.



Note: The data presented in Figure 4 provide an example of ozone risk estimation at the State level. Biosite categories on the x axis represent the risk of probable ozone injury to ozone-sensitive tree species in South Carolina in 2002. More than 16 million cubic feet of tree volume was categorized for risk of ozone injury. Approximately 6 million cubic feet falls into the no risk category while just over 10 million cubic feet of tree volume falls into the low to moderate risk categories. Fifty-three percent of the total categorized tree volume includes tree species that are ozone sensitive.

In this example, estimates are presented in terms of tree volume. However, other useful population estimates include the proportion of forest land and the acres of forest land in each biosite index category. Refer to Status Estimation, page 6 for the procedures used to estimate bioindicator attributes for forested areas.

Appendix II: Ozone Sensitivity of Tree and Shrub Species

The abbreviations used to assign sensitivity in the following tables are as follows: Sen = ozone sensitive, ModSen = moderately sensitive, InSen = ozone insensitive, Unk = unknown ozone sensitivity because there is evidence from different observers that is conflicting. Regional analysts should review both tables because species listed as eastern may be found in limited areas in Western States and visa versa. Additional ozone sensitivity listings of non-woody, forest species can be found at: http://www2.nature.nps.gov/air/Pubs/pdf/BaltFinalReport1.pdf.

Table 7. List of eastern tree and shrub species and their ozone sensitivity.

Table 8. List of western tree and shrub species and their ozone sensitivity.

fi	*Abies balsamea*
	Acer negundo
	Acer pensylvanicum
	Acer rubrum
	Acer saccharinum
	Acer saccharum
	Acer spicatum
	Aesculus glabra
	Aesculus octandra
	Ailanthus altissima
	Alnus rugosa
	Amelanchier arborea
	Amelanchierlaevis
	Asimina triloba
	Betula alleghaniensis
	Betula lenta
	Betula papyifera
	Betula populifolia
	Carya cordiformis
	Carya glabra
	Carya ovata
	Carya sp.
	Carya tomentosa
	Celtis occidentalis
	Cephalanthus occidentalis
	Cercis canadensis
	Cladrastis lutea
	Clematis virginiana

fl[illegible]

Ilex opaca
Juglans nigra
Juniperus virginiana
Larix laricina
Liquidambar stryraciflua
Lindera benzoin
Liriodendron tulipifera
Lyonia ligustrina
Magnolia acuminata
Malus sp.
Nyssa sylvatica
Oxydendrum arboreum
Parthenocissus quinquefolia
Philadelphus coronarius
Picea abies
Picea glauca
Picea mariana
Picea rubens
Pinus banksiana
Pinus echinata
Pinus pungens
Pinus resinosa
Pinus rigida
Pinus strobus
Pinus sylvestris
Pinus taeda
Pinus virginiana
Platanus occidentalis
Populus balsamifera
Populus deltoides
Populus grandidentata
Populus tremuloides
Prunus americana
Prunus pensylvanica
Prunus serotina
Prunus virginiana
Quercus alba
Quercus coccinea
Quercus ellipsoidalis
Quercus falcata
Quercus imbricaria
Quercus macrocarpa
Quercus palustris
Quercus phellos

	Rubus cuneifolius
	Salix nigra
	Sambucus canadensis
	Sassafras albidum
	Symphoricarpos albus
	Thuja occidentalis
	Tilia americana
	Triadica sebifera
	Tsuga canadensis
	Ulmus americana
	Ulmus rubra
	Vitis labrusca

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fi

	Alnus rubra
	Alnus sinuata
	Amelanchier alnifolia
	Fraxinus anomala
	Lonicera involucrata
	Pinus contorta[1]
	Pinus jeffreyi
	Pinus ponderosa[2]
	Pinus radiata
fi	*Physocarpus capitatus*
	Physocarpus malvaceus
	Populus fremontii
	Populus tremuloides
	Populus trichocarpa
fi	*Pseudotsuga menziesii*
	Quercus kelloggii
	Rhus trilobata
	Rubus parviflorus
	Salix gooddingii
	Salix scouleriana
	Salix sp.
	Sambucus mexicana
	Sambucus racemosa
	Symphoricarpos albus
	Symphoricarpos sp
	Tsuga heterophylla
	Vaccinium membranaceum
	Vaccinium sp.

Pinus contorta *latifolia*
Pinus ponderosa *ponderosa*

fi

Appendix III: Documents for Ozone Information Management

Documents to assist FIA regional analysts with ozone information management:

1. Flow of Ozone Data from the Field to the FIA Information Management System
2. Ozone Standard Summary Tables in the FIA Data Base (FIADB)
3. Formulation of the Biosite Index
4. SAS Code for Biosite Tables and Maps
5. Contact List for Ozone Data Management

To obtain the following documents, email Gretchen Smith at gcsmith@nrc.umass.edu

1. Computation specifications for derived ozone data in FHM
2. Ozone bioindicator attribute definitions for FIADB
3. Ozone data collection start dates by state and year
4. Crosswalk tables for tracking changes to the ozone sample from 1994 to the present
5. Sample biosite field map
6. National ozone risk map for the sampling period 1994-1998
7. National ozone risk map for the sampling period 1999-2002
8. National map of the 7-year average ozone exposure 1996-2002

F O D F FIA I M

The goals of ozone information management are to clean up the ozone data files collected by the field crews, correct the regular crew and QA crew data files so they are compatible with the leaf voucher data, and generate ozone summary statistics suitable for further analysis and reporting. The summary statistics are used to generate an ozone risk map and population metrics as described in the main body of this document.

Step 1:
Each Regional Analyst works with the raw data file entered by the field crew and the validation file created by the National Indicator Advisor.

Step 2:
The Regional Analyst/P3 Data Processor in each region takes the raw data files entered by the field crew and the validation file created by the National Indicator Advisor and loads both into NIMS (National Information Management System). The P3 LAB system-checker program determines errors between the validation file and the raw data. Differences between these two files must be resolved at the regional level through direct communication between the National Indicator Advisor and the Regional Analyst. Error resolution requires changes to both the raw data file and the validation file.

Note: It is sometimes helpful to resolve differences between these two files before loading the data into NIMS. Software to assist with this process is available. Once the data are loaded, the checker program is used as a final edit.

Step 3:
The Regional Analyst/P3 Data Processor in each region runs the P3 LAB system-report program on the validated ozone data. The report program creates three ozone standard summary tables: OZONE_PLOT_SUMMARY, OZONE_SPECIES_SUMMARY, and OZONE_BIOSITE_SUMMARY.

Step 4:
The Regional Analyst/P3 Data Processor contacts Brian Cordova, FIA-IM, at: cordovab@unlv.nevada.edu. Each region's data are captured and placed on the national NIMS Web site. Sensitive information is stripped (NULLED), and the remaining information is posted on the national FIA database (FIADB) P3 Web site and the FIADB Data Mart, which is the data distribution system to the public.

> Note: Step 2 instructs the Regional Analyst to load the data into NIMS. Until the new TALLY program is completed, the raw TALLY files are parsed using TALLY Cracker and inserted into the LOAD tables in NIMS. The data are moved from the LOAD tables to the NIMS tables through the front-end, which is a graphical interface used to load and drop data, run computations and reports, etc. The front-end is again used to load the validation file and create a report of any errors. In the future, Step 4 will be a direct upload to the NIMS FIA-P3 Web site via the front-end interface.

Additional Steps:
The NIMS ozone summary tables provide biosite summary statistics suitable for preliminary reports at the State and regional levels (see Output Tables and Maps). SAS routines are available that generate additional summary statistics from the validated ozone files. For example, one routine generates all the necessary values to create a summary table that presents numbers of biosites evaluated, number of plants sampled by species, and percentage of sampled plants in each injury severity category. Another SAS routine is available that generates a biosite list with presence or absence of ozone injury to use for an ozone site distribution map. This map is useful for tracking changes over time in the number and distribution of plus ozone sites across a State or region.

The OZONE_BIOSITE_SUMMARY table includes the biosite-level ozone injury index referred to as the Biosite Index (BI). Using a 5-year rolling average of the BI, an FIA Spatial Data Analyst creates the national risk map of probable ozone injury. A new map is produced every year. This map surface is stored in the FIADB Data Mart so that it can be extracted by Regional Analysts, in whole or in part, as needed. FIA Spatial Data Services uses the national map to generate an estimated BI value for every P2 ground plot. This biosite attribute is added to the larger P2 table of plot attributes in the FIADB Data Mart. This will allow FIA analysts to examine relationships between bioindicator attributes and other indicators of tree growth, forest health, and condition. FIA Spatial Data Services also maintains a master list of geographical coordinates for the ozone sampling grid and crosswalk tables that link biosites on the FHM-P3 grid (1994-2001) to biosites on the FIA Ozone Grid (2002-present).

Analysts responsible for 5-year reports or comprehensive regional reports should refer to the main body of the text of this document for detailed guidance on the analytical techniques used to generate FIA P2 plot-level metrics of the ozone data. The companion user guide for the ozone indicator provides (1) examples of output tables and maps using real data, and (2) additional interpretive guidance on the issues associated with ozone air quality and forest health.

F B I (BI)

N : The ozone indicator site-level biosite index was formulated with the assistance of David Randall, Statistician for the USDA Forest Service, Northeastern Area, Washington Office.

<u>Notes on the formulation:</u>
There are 3 components to the formulation: (1) the amount of injury, (2) the severity of injury, and (3) the incidence of injury on the site. The formulation selected associates these three components at the individual plant level. This suggests that the ozone injury response of each individual plant is important. This is biological reality and better than lumping all species together.

The calculation is intuitive. A mean value is calculated that truly represents a proportion of the population at both the plant level and the species level. An arithmetic mean is then taken for the "n" species on the plot.

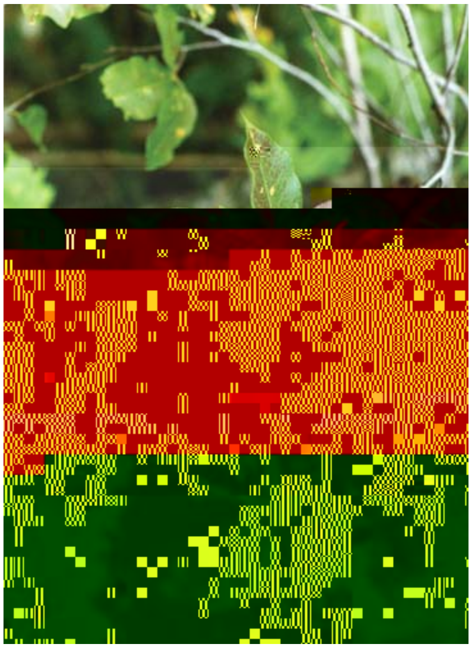
<u>Notes on method:</u>
Each plant observed by the field crew is rated for the percent of the plant that is injured (i.e., injury amount) and the average severity of injury (i.e., injury severity) using a modifi

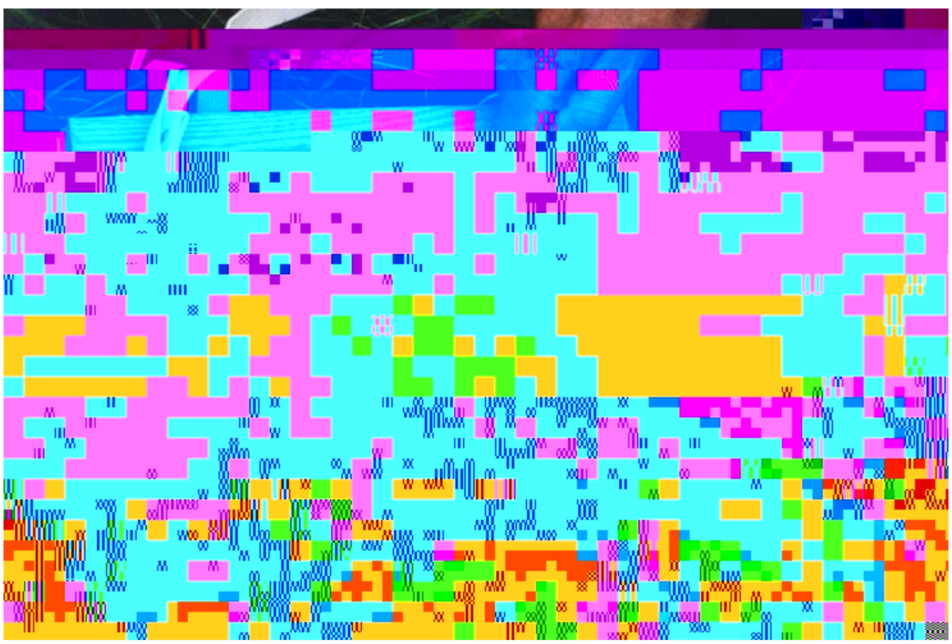
for download from the FIADB Data Mart (the data distribution system to the public). The first map product is the national ozone risk map that provides an interpolated surface of probable ozone injury across the landscape. The second map product is an interpolated surface of ambient ozone concentrations. Data users select their area of interest (e.g., state, region, or eco-region) from these two map products, and use the procedures outlined in the ozone estimation document to calculate and interpret population metrics for the ozone indicator. If you have trouble accessing Web sites or data files, contact the National Ozone Advisor, the FIA analyst in your region, or Brian Cordova at cordovab@unlv.nevada.edu.

Smith, Gretchen C.; Smith, William D.; Coulston, John W. 2007. Gen. Tech. Rep. NRS-20. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 34 p.

Ozone is an important forest stressor that has been measured at known phytotoxic levels at forest locations across the United States. The percent forest exhibiting negative impacts from ozone air pollution is one of the Montreal Process indicators of forest health and vitality. The ozone bioindicator data of the U.S. Forest Service Forest Inventory and Analysis Program (FIA) are the only source of information available that documents plant injury from air pollution using consistent protocols. This document introduces the FIA ozone indicator and describes the sampling and estimation procedures of the national biomonitoring program. We provide background material on ozone, examples of bioindicator summary statistics, a description of spatial interpolation, and methods to estimate status and change in forested areas with respect to the occurrence of ozone injury from ambient ozone concentrations. The goal is to provide guidance to analysts and researchers on ways to incorporate ozone bioindicator data into reports and research studies. Periodic recommendations to analysts on improved analytical techniques will be made. Analysts are encouraged to consult the companion user guide for additional guidance on interpreting the ozone biomonitoring data and reporting on the issue of ozone and forest health for the FIA program.

KEY WORDS: air quality, bioindicator species, biomonitoring, forest health, kriging, ozone, ozone sensitive, risk assessment, spatial interpolation





Capitalizing on the strengths of existing science capacity in the Northeast and Midwest to attain a more integrated, cohesive, landscape-scale research program