

Chapter 2

What is the role of demographic factors in air pollution and forests?

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Abstract

The advent of the twenty-first century finds us with many reasons to consider scenarios for global change and air pollution in concert. During the decade of the 1980s, there were large research efforts in Europe and North America focused on the ecological consequences of air pollution and acidic deposition. These efforts, however, largely ignored climate change. During the decade of the 1990s, similar major research efforts were initiated globally with a focus on the consequences of global climate change. At this point, however, there has been limited research focused on understanding the interactions of multiple factors, including air pollution, insects and diseases, and even fewer attempts to incorporate such factors into modeled projections of climate change impacts on forest distribution or productivity. Twenty-first century scenarios for changes in spatial patterns of air quality will not only be driven by natural weather and climate variability, but also by changes in demographics, land use, and economic growth. These factors may result in quite different patterns on a global, regional (continental), or subregional scale from those observed over the past century. Changes in both climate and air pollution are the result of dynamic processes that will influence each other, and that will develop over time. Because of inherent uncertainties in knowledge of the processes affected, our understanding of the magnitude of the responses are equally uncertain. For the community of scientists engaged in research on the relationships among air pollution, climate change, and forest health and productivity, the need of landowners and other decision-makers for science-based adaptive strategies should challenge us, and makes a compelling case for an aggressive research agenda.

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1. Introduction

The words of Kenneth Boulding, the ecological economist, remind us “We have to be prepared to be surprised by the future, but we don’t have to be dumbfounded”. We are also reminded of the words of former baseball player Yogi Berra, when he once said “If you don’t know where you’re going, you end up somewhere else”. Contemplating the 21st Century from here at its very beginning seems to be much like Yogi described. It is the wild card out there, the thing we might not anticipate, that makes prediction into the future so challenging. In this paper, we examine recent demographics that may help predict this century’s trajectories of major air pollutants and climate change.

Our goal should be to break out of our typically reactive mode—to learn to anticipate change and deal with emerging issues in advance, before simple challenge matures into crisis, and before our decision space has shrunk to a consideration of the lesser of evils. We need to devise mechanisms that will enable us to look “beyond the headlights”, to see the landscape before us, and to adjust our course to follow the terrain. Lack of foresight has sometimes hampered our collective ability to deal with challenging issues related to air quality, and agencies have sometimes been slow to respond to changes in scientific understanding, or the expectations of the public. Tradition, professional training, and legislative direction have proven to be uncertain guides to the future in a rapidly changing society, and the one thing that seems certain, is that the advent of the twenty first century will bring rapid change.

2. Analysis

As one thinks about global climate change and air pollution and the scenarios for each of them into the twenty-first century, one asks “What do we know about the factors that drive air quality, and what do those factors tell us about the future that complicate our view?” What does the future look like?

There are several ways to view this question, and in this paper we will briefly examine a number of large-scale trends that seem to be redefining our society. Many of the examples will be North American in context, but are relevant to much of the world today, or certainly will be within this century. Largely, they can be categorized into social, demographic, and economic factors; into feedbacks to air quality from those social, demographic, and economic factors through their patterns and distribution on the landscape; and through their interactions with a host of other factors, physical, biological, and social.

We have learned over the past 20 years or so that we can no longer afford the luxury of single factor assessment of issues. This became obvious during the days of atmospheric deposition (“acid rain”) assessments (Irving, 1991), and

has been reaffirmed repeatedly by the research and assessment activities that have followed (Fox and Mickler, 1996; Mickler et al., 2000; Karnosky et al., 2001). We live in a complex world, and in order for our research to be relevant, we must be able to capture that complexity.

Another thing that seems certain is that over the next century, patterns of social, demographic, and economic activity will shift—globally, nationally, and regionally. Let us consider some of the shifts that have the potential to influence air quality.

2.1. Demographic change

- There will be increased diversity in the American population. By 2050, racial and ethnic minorities will comprise half of all Americans; 86% of immigration is now non-European. Over the next 50 years, 90% of the population growth will come from racial and ethnic minorities.
- America is aging. One hundred years ago, only 4% of the US population was over 65; by 2020, 21% are projected to be over 65, and by 2050, projections are for more than 4 million centenarians (compared to just 70 000 today).
- Shifts in the spatial distribution of population are occurring. In the US, movements out of the North and East, to the South, and West are occurring. Shifts of this nature have been underway for some time, but future projections are for them to continue, or to become more pronounced. People are moving closer to forest resources, bringing NO_x, VOCs and commuter miles with them. On a global scale, nearly 700 000 immigrants relocate to the United States each year, shifting population hemispherically, if not globally. The implication for air pollution, of course, is in the shift of people, cars, jobs, industries, etc, from one place to another, and the resulting changes in precursor emissions, regional atmospheric chemistry, and deposition.
- Shifts are occurring from a manufacturing economy to a service and information technology one. Competition from a global labor market and technological changes making “just in time delivery” a global, not a local concept, and shifting manufacturing emissions globally. It is thus not surprising that total sulfur deposition is expected to rise dramatically in developing countries over the next 50 years (Fig. 1, Fowler et al., 1999).
- A change from rural to urban populations is occurring. Americans are increasingly becoming more urban and suburban, less rural. Political representation will shift more away from rural counties. Between 1969 and 1990, urban areas in the US doubled in spatial extent and now occupy some 3.5% of the US (Dwyer et al., 2003). The expansion of urban areas has not only been in response to population growth; but also to the movement of busi-

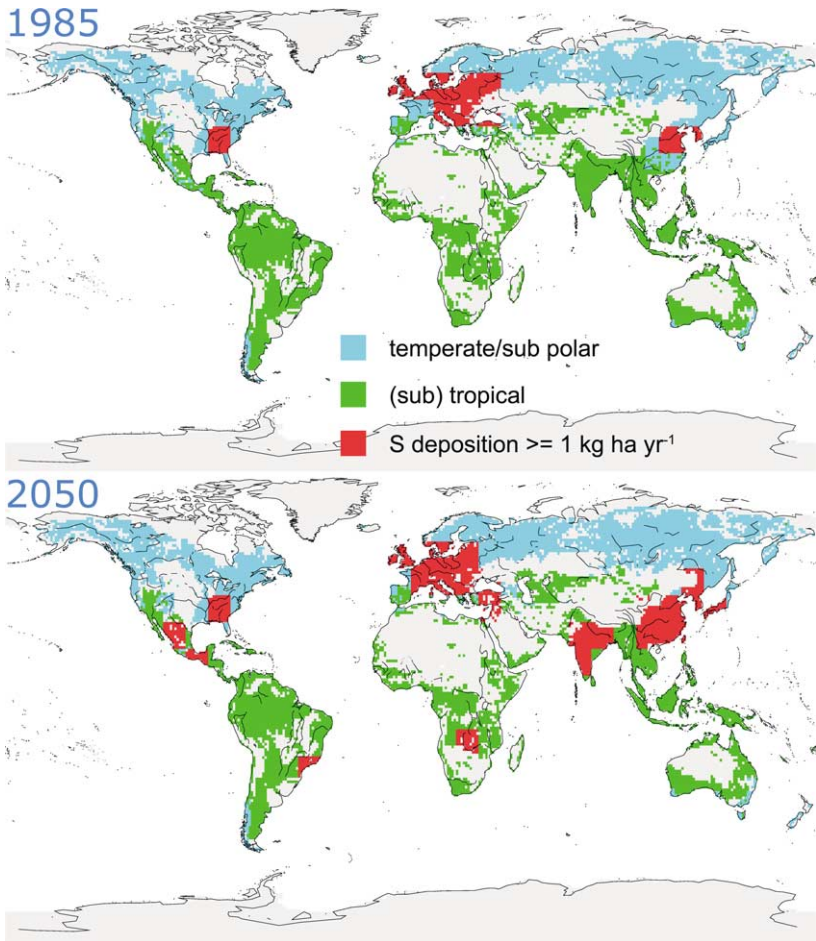


Figure 1. The estimated increase in forest area receiving elevated inputs of sulfur (S) deposition is seen in this map of S deposition in 1985 and the projected S deposition map projected for 2050 (from Fowler et al., 1999).

nesses, industry, and residences from the inner city to the periphery and outlying areas. This movement has been fueled in part, by limitations in living, working and doing business in inner city areas; and in part, by the relative attractiveness of some suburban and ex-urban locations. Many of those who do move to the rural areas will take their urban attitudes, expectations, and incomes with them; they will **reside** in rural America, but will not culturally be **of** rural America, nor economically dependent on it.

2.2. *The information revolution*

No matter which futurist you consult, virtually all cite the role of information technology in shaping the future. Access to information has been democratized and that trend will only to continue to accelerate. Each of us now has the ability to access data in vast quantities, and to render that data into information for decision-making. Today, there are almost 200 million people on the internet worldwide. This information capacity will increasingly make available virtual businesses, allowing individuals to choose where they live based on their demand for quality of life, and again, potentially shifting the pattern of people on the landscape.

2.3. *Material wealth*

Wealth and disposable income will continue to increase, on average. But, gaps between wealth and poverty will remain. Disposable wealth, increased leisure time, flexible hours, work at home, educational attainment, and technological sophistication will increase. One futurist predicts that by 2020, 60% of all US consumers will be college educated, work in an information intensive environment, have an income in excess of \$50 000 in 1999 dollars, and will have access to high speed, interactive multimedia communication devices in their homes.

2.4. *Primary production*

American society will continue to see a decreasing reliance on—and identification with—primary production. The shift to a service and information economy will create an even greater gulf between traditional commodity users of forest resources, and the rest of the nation, and may feed resentment on the part of rural, commodity-dependent communities that feel abandoned by the larger society and economy.

2.5. *Global integration*

There will be greater global integration—manifesting itself in several ways that hold implications for forests and forest health. Markets for material goods, including timber will become increasingly global markets. Markets for ecotourism and forest recreation will do the same. There will be growing pressures to meet global standards for environmental quality, on the model of the Montreal agreements, and the Kyoto protocol. Global demands on forests worldwide will increase at unprecedented rates as total population goes from 6 bil-

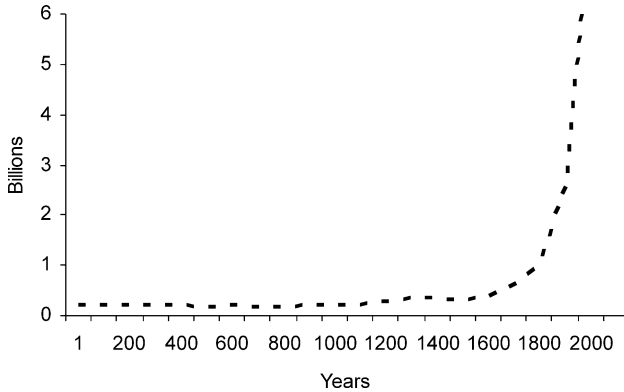


Figure 2. Worldwide population growth.

lion to 10 or 11 billion (Fig. 2) and environmental pressures continue to limit the extent of “working” forests.

2.6. Environmental quality

The demand for increased environmental quality will continue. The trend of the past 30 years has turned out to not be a passing phenomenon. Current societal demands for open space, clean water, clean air, free-flowing streams, fish and wildlife, endangered species, recreational access to unspoiled places, and a sustainable environmental legacy will remain a dominant feature of the political and policy landscape well into the 21st century. The developing conflicts between developers in natural areas and environmentalist extremists who have recently taken on a radical philosophy of vigilantism towards stopping development (i.e., arson and extreme vandalism) will continue to grow. There is evidence that people are willing to move substantial distances to a preferred retirement location. This is likely to be a logical extension of the increasing mobility of the population. Where people decide to retire can become an important force for change in the distribution of individuals over the landscape. It is not clear to what extent retirement patterns will differ among racial and ethnic groups. However, the retirement opportunities and decisions of individuals in these groups are likely to have important implications for shifts in the location of the US population in the years ahead.

2.7. Air pollution and climate change research

The established pattern of chronic under-investment in air pollution and climate change research will likely continue. Despite greater wealth of individ-

uals, we can anticipate increased competition for limited federal dollars, over the next 30 years or more. The reason for this apparent contradiction lies in our aging population. As baby-boomers retire over the next few years, the ratio of workers to pensioners will change, stretching the ability of the government to meet social needs, and intensifying the competition for federal dollars.

So what do these changes mean for air quality? Changing lifestyles, population patterns, and age structures may create patterns of regional air quality which differ significantly from the present over the course of the next century. Regulatory measures have resulted in up to 15% decreases in recent years in one-hour peak ozone (O₃) concentrations in the areas previously with the highest number of exceedances. However, projections are that the spatial extent of areas designated as non-attainment under the new 8-hour standard will increase, perhaps already due to some of the kinds of changes we have discussed. Ozone is potentially the most damaging of the major air pollutants in terms of negative impacts to forest growth and species composition (Fig. 3). In the eastern US, 20% of the forested land area is in counties that exceeded the National Ambient Air Quality Standard for O₃ in 1989. Use of the standard as the measure of impacted area probably underestimates the actual impact, however, since many sensitive plant species are known to experience growth reductions at levels as low as 50–60 ppb.

The forests of North America are vast and diverse, representing over 750 million hectares in the US and Canada. Projections for the effects of Global Climate Change on forest health include both increased growth and range of some forests, but also an increased frequency of declining health in others in response to increased biotic and abiotic stresses associated with climate warming (Houghton et al., 2001; IPCC, 2001). It is this more complex future environment, where changes in temperature and precipitation not only have direct consequences for forest growth, but indirect consequences on the atmospheric environment, and on insect and pathogen populations, that we are challenged to understand.

Collectively, the physiological effects of air pollutants are anticipated to either predispose forest trees to other stresses, or to amplify the negative effects of other stresses. McLaughlin and Percy (1999) recently provided insight for the eastern US, on the spatial consistency between the patterns of the most frequent occurrence of major disease problems as documented by forest surveys, and the patterns of the highest levels of ozone and acidic deposition across the region. While the data are inadequate to establish a statistical relationship between forest health and air quality, the circumstantial evidence is, none the less intriguing.

From a physiological perspective, the effects of increasing CO₂ and increasing temperature on net primary production, the effects of temperature on the frequency and severity of drought, and the effects of increasing nitrogen on

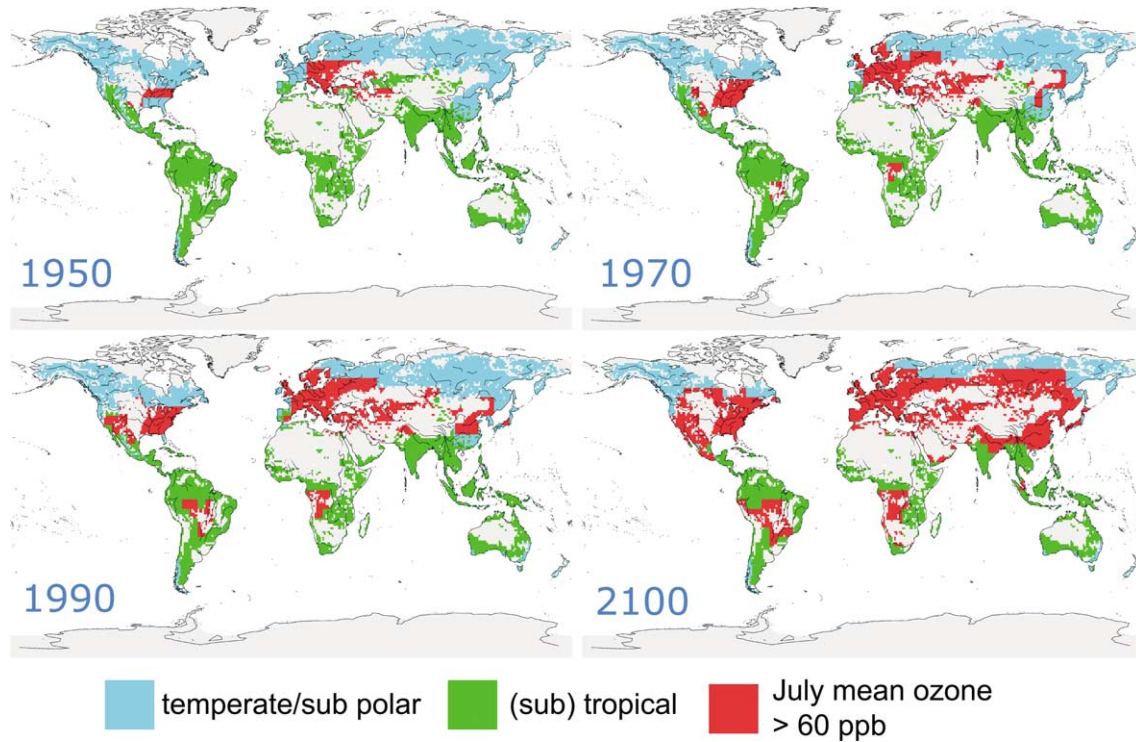


Figure 3. The increase in forest area receiving elevated ozone (July mean ozone > 60 ppb) from 1950 to 1990 and a projection for the year 2100 (from Fowler et al., 1999).

nutrient uptake and allocation to shoots and leaching from soils appear to be the most compelling components of climate change that could significantly influence forest sensitivity to biotic and abiotic stresses.

A wide variety of controlled studies now indicate that increasing CO₂ will lead to significant enhancement in leaf photosynthetic rates and increased net primary production of forest trees (Norby et al., 1999). Although very limited data are available for more mature forest trees (Karnosky, 2003), results to date suggest that positive growth responses are rather robust, in terms of absence of limitations by variations in supply of other resources. Warming temperatures, on the other hand, affects many essential forest processes and in many different ways. Most notably, the carbohydrate economy may be improved by extending the length of the growing season, but adversely impacted by the increased respiratory costs of temperature driven metabolic processes. In addition, warming temperatures will increase evapotranspiration, thus magnifying potential limitations of water supply on the amount and allocation of growth.

There is limited information available about the response of forest trees to air pollutant interactions, and several authors have suggested that increasing CO₂ might mitigate ozone-caused growth reductions (Volin and Reich, 1996; Volin et al., 1998). However, recent results with aspen bring this model into question (Isebrands et al., 2001; McDonald et al., 2002).

We believe at the policy level, current global models used for projecting the distribution and condition of forests in response to global change do consider increases in CO₂ and water availability, and increased temperature on forest growth. At present, these models do not consider the potential implications of regional air pollutants on forest growth processes, or on the predisposition of forest trees to other forms of biotic and abiotic stress (Percy et al., 2002).

3. Future pollutant scenarios

The current temporal trends of acidifying pollutant emissions show a marked contrast between the total emissions, which are increasing globally, but decreasing in Europe and North America. These trends will, over the next decade, appreciably reduce the areas of forest in Europe and North America currently receiving inputs of acidity in excess of 2 keq H⁺ ha⁻¹ annually. By 2050, more than half of the global forest subject to acidifying inputs in excess of that level will be in the tropics and subtropics—again, a significant shift in spatial pattern (Fig. 1) that appears to be closely linked to demographics as can be seen in the close relationship between the population density (Fig. 4) and pollutant deposition (Galloway et al., 2002; Galloway and Cowling, 2002).

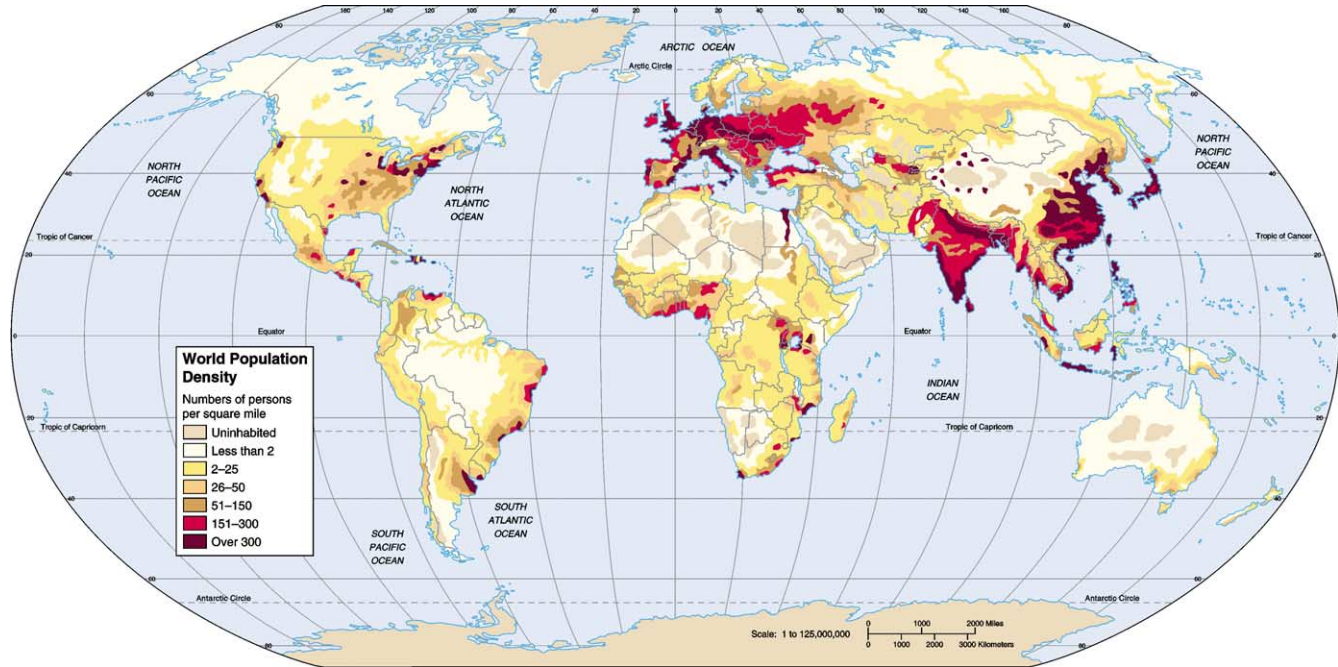


Figure 4. Worldwide population density (from US Department of Agriculture).

The photochemical oxidants, and O₃ in particular, have been shown to be major pollutants for forests globally, and to have increased rapidly throughout the last half century. Model forecasts of the global exposure of forest to O₃ (Fowler et al., 1999; Derwent et al., 2002) indicate continued increases in exceedance of thresholds for physiological effects, and probably also growth decreases (Fig. 3). The timescale of the projections is sufficiently long that important interactions between the effects of climate, CO₂ and O₃ on the responses of forests to O₃ are likely (Kickert and Krupa, 1990). The scale of the interactions is also likely to be of the same order as the direct effect of the O₃, so that significant positive or negative feedback is likely. The steady increase in deposition of nitrogen compounds with time is also likely to interact with climate change and CO₂ (Norby, 1998). Thus, the net effect on forest composition, productivity, and sensitivity to environmental stresses becomes very difficult to predict. There is little doubt that given the scope for environmental changes in the chemical and physical climates to which forests will be exposed over the next century that current models could simulate dramatic changes to the composition of the forested landscape. It is much more likely that the actual effects which occur will be unforeseen, and that they may be either positive or negative, and only extensive monitoring and research programs can provide the evidence sufficiently early to avoid significant social and economic consequences.

4. Research needs

1. Innovative and integrated approaches are needed to study the effects of CO₂, temperature, precipitation, O₃, N and S deposition on forests, and the potential interactions of these factors with forest insect pests and disease organisms.
2. An increased basic understanding of current forest disturbances is needed to determine how disturbances will interact with air pollution and climate change to shape future forests.
3. Prediction of climate and change in climate at scales of resolution relevant to ecosystems on the landscape will require major advances in modelling and some experimental ground truthing.
4. Understanding of the relationships between climate/weather patterns, trace gases, and the interactions of these factors with biological species at multiple scales is needed.
5. Integration of climate change, air pollution impacts, and land use change into major ecological models are needed to increase our predictive capabilities for forest growth, biodiversity, and ecosystem functions.

6. Improved integration of socioeconomic considerations into the development of future scenarios of climate response and air pollution impacts is needed to better understand the demographic implications of global change.

5. Summary

In summary, 21st century scenarios for changes in spatial patterns of air quality will not only be driven by natural weather and climate variability, but also by changes in demographics, land use, and economic growth. These factors may result in quite different patterns on a global, regional, or continental scale from those observed over the past century. Alterations in both climate and air pollution are the result of dynamic processes that will influence each other, and that will develop over time. Because of inherent uncertainties in our knowledge of the processes affected, our understanding of the magnitude of the response is equally uncertain. For the community of scientists engaged in research on the relationships among air pollution, climate change, and forest health and productivity, the needs of landowners and other decision makers for science-based adaptive strategies should challenge us all. Furthermore, a compelling case for an aggressive research agenda regarding research on the impacts of air pollution and climate change can easily be made.

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