United States Environmental Protection Agency

Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act:

EPA's Response to Public Comments

Volume 6: Impacts and Risks to Public Health and Welfare: Agriculture and Forestry

Impacts and Risks to Public Health and Welfare: Agriculture and Forestry

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FOREWORD

This document provides responses to public comments on the U.S. Environmental Protection Agency's (EPA's) Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, published at 74 FR 18886 (April 24, 2009). EPA received comments on these Proposed Findings via mail, e-mail, and facsimile, and at two public hearings held in Arlington, Virginia, and Seattle, Washington, in May 2009. Copies of all comment letters submitted and transcripts of the public hearings are available at the EPA Docket Center Public Reading Room, or electronically through http://www.regulations.gov by searching Docket ID *EPA-HQ-OAR-2009-0171*.

This document accompanies the Administrator's final Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act (Findings) and the Technical Support Document (TSD), which contains the underlying science and greenhouse gas emissions data.

EPA prepared this document in multiple volumes, with each volume focusing on a different broad category of comments on the Proposed Findings. This volume of the document provides responses to public comments regarding agriculture and forestry.

In light of the very large number of comments received and the significant overlap between many comments, this document does not respond to each comment individually. Rather, EPA summarized and provided a single response to each significant argument, assertion, and question contained within the totality of comments. Within each comment summary, EPA provides in parentheses one or more lists of Docket ID numbers for commenters who raised particular issues; however, these lists are not meant to be exhaustive and EPA does not individually identify each and every commenter who made a certain point in all instances, particularly in cases where multiple commenters expressed essentially identical arguments.

Several commenters provided additional scientific literature to support their arguments. EPA's general approach for taking such literature into consideration is described in Volume 1, Section 1.1, of this Response to Comments document. As with the comments, there was overlap in the literature received. EPA identified the relevant literature related to the significant comments, and responded to the significant issues raised in the literature. EPA does not individually identify each and every piece of literature (submitted or incorporated by reference) that made a certain point in all instances.

Throughout this document, we provide a list of references at the end of each volume for additional literature cited by EPA in our responses; however, we do not repeat the full citations of literature cited in the TSD.

EPA's responses to comments are generally provided immediately following each comment summary. In some cases, EPA has discussed responses to specific comments or groups of similar comments in the Findings. In such cases, EPA references the Findings rather than repeating those responses in this document.

Comments were assigned to specific volumes of this Response to Comments document based on an assessment of the principal subject of the comment; however, some comments inevitably overlap multiple subject areas. For this reason, EPA encourages the public to read the other volumes of this document relevant to their interests.

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Acronyms and Abbreviations

AMO	Atlantic Multi-Decadal Oscillation
ANPR	Advance Notice of Proposed Rulemaking
ACIA	Arctic Climate Impact Assessment
CCSP	U.S. Climate Change Science Program
CO_2	carbon dioxide
ENSO	El Niño-Southern Oscillation
EPA	U.S. Environmental Protection Agency
EU	European Union
FACE	Free-Air CO_2 Enrichment
IPCC	Intergovernmental Panel on Climate Change
GHG	greenhouse gases
NRC	National Research Council
PDO	Pacific Decadal Oscillation
ppm	parts per million
TSD	Technical Support Document
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program

6.0 Impacts and Risks to Public Health and Welfare: Agriculture and Forestry

6.1 Agriculture

Comment (6-1):
Several commenters (e.g., 2972.1, 3136.1, 3283.1, 3311.1, 3347.1, 3394.1, 3596.2, 3596.3, 3722, and 3747.1) state that the climate impacts evidence as summarized in the Technical Support Document (TSD) with respect to agriculture do not support the Administrator's endangerment finding. The commenters conclude that it would be arbitrary and capricious to base the endangerment finding on what they believe are vague statements and selective information found in the TSD regarding impacts and risk to agriculture.

Response (6-1):
The specific issues that underlie these comments are addressed in the responses throughout this volume, and other volumes of the Response to Comments document. With regard to the commenters' conclusion that the current science does not support an endangerment finding with respect to agriculture, we disagree based on the scientific evidence before the Administrator. See the Findings, Section IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for details on how the Administrator weighed the scientific evidence underlying her endangerment determination in general, and with regard to the agriculture sector in particular.

Comment (6-2):
Several commenters (e.g., 3394.1, 3449.1, 3722, and 3747.1) request clarification of EPA's conclusions regarding the net effects of climate change on agriculture (i.e., if EPA is concluding that the positive effects of climate change on agriculture will ultimately be outweighed by negative effects or that the positive effects on agriculture will ultimately be outweighed by negative effects on other sectors). At least one commenter asserts that the TSD presents specific findings of effects of climate change that may occur for some parts of the agricultural system in the United States, but does not provide sufficient information to judge the overall consequences and risks to U.S. agriculture posed by greenhouse gases (GHGs). Other commenters (e.g., 1594.1, 3136.1, 3236.1, and 4003) conclude that the scientific evidence indicates that positive benefits of global warming and rising atmospheric CO_2 on agriculture will outweigh any adverse effects.

The commenters identify the following specific issues regarding net (adverse and beneficial) effects of climate change on agriculture:

1) A commenter asserts that the TSD's discussion of positive and negative impacts is not consistent with the U.S. Climate Change Science Program's (CCSP) 2008 report SAP 4.3 (2008e), in which the U.S. Department of Agriculture (USDA) concludes that most crops for which there are data will experience net productivity gains, despite certain projected negative impacts resulting from temperature increases, precipitation changes, and increased pest and disease activity.

2) Some commenters argue that the TSD's conclusions regarding net effects are not consistent with reports from the Intergovernmental Panel on Climate Change (IPCC) and the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (Reilly et al., 2001), which all indicate an overall neutral to positive effect on agricultural output from increased CO_2 and warmer temperatures. These commenters cite positive effects of climate change including increased aggregate yields of rain-fed agriculture by 5% to 20%, the direct effects of elevated CO_2 levels on crop yields, the extension of forage production in to late fall and early spring, and the reduction in livestock deaths from warmer winter temperatures.

3) Some commenters indicate that there is no supporting factual information to conclude that increased CO_2 will negatively impact crops, and that even the TSD acknowledges that research on the combined effects of elevated CO_2 and climate on pests, weeds, and disease is still insufficient to conclude a net detrimental effect on U.S. and world agriculture. One commenter (5846) indicates that as the length of growing season increases, the line marking the higher latitude limits to crop growth moves towards the poles and killer frosts become less frequent; therefore, we can expect agriculture to thrive.

4) Some commenters accuse EPA of "cherry picking" information about the potential for negative health impacts of plants like poison ivy or allergenic plants whose increased health and vigor leads to negative reactions in some people. The commenters argue that the net effects of rising CO_2 levels will be positive for society because increased corn production greatly trumps increased poison ivy production.

5) At least one commenter indicates that although the TSD repeats the IPCC and CCSP conclusions, it does not independently investigate livestock mortality rates in extreme heat or extreme cold, and therefore cannot explain the summary conclusion, particularly given that the TSD in Section 4(c) conceded spring and winter show the greatest increases in temperature, and daily minimum temperatures show more warming than daily maximum temperatures. As such, it would be logical to conclude that fewer livestock deaths from warmer winter temperatures would entirely offset, if not outweigh, livestock loss during summer seasons.

Response (6-2):

See Section IV.B.2 of the Findings for the Administrator's consideration of the various effects to food production and agriculture for purposes of making the endangerment finding to public welfare. Here, we respond to the specific issues raised by commenters.

1. After careful review, we disagree with the commenters that the conclusions of the scientific assessment literature as summarized in the TSD are inconsistent with the CCSP's 2008 report SAP 4.3 (2008e). For example, Section 9 of the TSD cites numerous conclusions directly from the CCSP SAP 4.3 report (Backlund et al., 2008a) regarding projected climate impacts on agriculture. The commenter may have misinterpreted the CCSP's conclusions about the net effects of climate change on agriculture because, although Backlund et al. (2008a) acknowledge some benefits for grain and oilseed crops with increased CO_2 and temperature, they also concluded that as temperature rises, particularly in the later half of the century, these crops will increasingly begin to experience failure, especially if climate variability increases and precipitation lessens or becomes more variable. Further, the TSD summarizes conclusions specific to crop production from the CCSP report that indicate the 30-year outlook for U.S. crop production is relatively neutral. However, the CCSP assessment also concludes the outlook for U.S. crop production over the next 100 years would not be as optimistic, if temperature continues to rise along with climbing CO_2 concentrations (Hatfield et al., 2008). Therefore, we conclude that the TSD's summary of both positive and negative climate change effects on agriculture is consistent with and appropriately reflects the conclusions of this major scientific assessment report. Importantly, we note crop response to changes in climate variables (irrespective of direction or magnitude) is but one aspect the Administrator considers in terms of evaluating impacts and effects on food production and agriculture both in the near term and over the longer term.

2. We have carefully reviewed the TSD and the literature cited by the commenter and strongly disagree that the conclusions of the scientific assessment literature as summarized in the TSD are

Further, we note the TSD summarizes precisely the same findings referred to by the commenters. For example, the TSD indicates the IPCC finding of a projected increase in aggregate yields of rain-fed agriculture by 5% to 20%, but with important variability among regions (Field et al., 2007). In addition, the TSD clearly states the IPCC finding that increased average warming leads to an extended growing season, especially for northern regions of the United States. Thus, we conclude that information as summarized in the TSD is consistent with the major assessment literature in terms of identifying the benefits to the agricultural sector. However, we do not agree that these reports and other evidence compiled in the TSD indicate that beneficial effects will be uniformly distributed, or uniformly dominant over adverse effects, as a result of climate change in the future, particularly over the long term. See additional responses to comments on specific impacts and effects to agriculture in this volume.

3. The commenters assert that there is no supporting factual information to conclude that increased CO_2 will negatively impact crops. Section 9 of the TSD summarizes the most recent body of scientific assessment literature regarding the likely adverse and beneficial effects of climate change on United States agriculture. With regard to adverse effects, the TSD summarizes multiple lines of evidence based on observations and research that indicate weeds, pests, and disease will positively respond to increasing levels of CO_2 and warming temperatures, which present significant challenges to agriculture operations. For example, as described in the TSD, weeds respond more positively than most cash crops to higher temperatures and CO_2 levels (Hatfield et al., 2008), which increase stress on crop plants and the need for pest and weed control (Karl et al., 2009). In addition, rising temperatures allow both insects and pathogens to expand their geographic ranges northward where they have been historically restricted due to colder temperatures (Karl et al., 2009). Furthermore, research has shown that the most widely used herbicide used in the United States (glyphosphate), loses its efficacy on weeds grown at CO_2 levels that are projected to occur in the coming decades (Wolfe et al., 2007). In addition, as summarized in the TSD, agricultural crops are sensitive to various climate-related variables (i.e., heavy precipitation, drought, extreme temperatures and other disturbances). We therefore conclude that the TSD's summary of projected climate impacts (both positive and negative) on agriculture is based on scientific evidence and appropriately reflects the conclusions of the body of scientific literature. Section 9 of the TSD provides a balanced discussion of the projected adverse and beneficial impacts of climate change on agriculture. Regarding the comment that agriculture will thrive due to extended growing seasons in the Arctic and lack of killer frosts, we find that this assertion is unsupported by the science, which finds that both adverse and beneficial effects from climate change are likely. We note the commenter did not provide literature to counter the conclusions summarized in the TSD.

4. We strongly disagree with the commenter that EPA has "cherry picked" information about negative health effects of certain plants resulting from climate change. Sections 7 and 9 of the TSD include information on both the positive and negative effects of climate change on aeroallergens, pollen production, plant toxicity, and agriculture. Therefore, we find that the TSD's summary of projected climate impacts on agriculture was reasonable and appropriately

5. Regarding the comment that EPA did not conduct an independent investigation of livestock mortality rates in extreme heat or extreme cold, see Volume 1 for our response to comments alleging that EPA must conduct its own scientific assessment rather than relying on the existing assessment literature. The TSD relies on major synthesis documents of the IPCC and CCSP regarding the potential impacts to livestock production from climate change. For example, as indicated in the TSD, the CCSP concludes higher temperatures will very likely reduce livestock production during the summer season, but these losses will very likely be partially offset by warmer temperatures during the winter season. The commenter does not provide supporting scientific literature to support his claims that fewer winter livestock deaths would completely offset increased summer livestock mortality. As summarized in the TSD in Section 4(k), widespread changes in extreme temperatures have also been observed in the last 50 years. We conclude the TSD provides a balanced and accurate synthesis of the science regarding potential changes in livestock productivity and disagree with the commenter that observed trends in daily temperature alone, which do not represent projected changes in extreme conditions, provide evidence that livestock mortality will be offset or increase.

Comment (6-3):

One commenter (3394.1) states that Section 9 of the TSD exhibits significant bias because it does not attempt to quantify the relative impacts of positive and negative effects on agriculture. The Agency only presents quantitative information in instances where it supports an argument for negative climate impacts on agriculture. For example, the TSD cites the IPCC conclusion that "at ambient CO_2 concentrations of 550 ppm, crop yields increase under unstressed conditions by 10% to 25% for C3 crops, and by 0% to 10% for C4 crops." Yet, without reasoning, EPA dismisses this potential benefit of GHG emissions as small.

Response (6-3):

The TSD explicitly summarizes both beneficial and adverse effects to agriculture from changes in climate and provides quantification where such information is available. For example, as indicated in the TSD, the IPCC finds that moderate climate change in the early decades of the century is projected to increase aggregate yields of rain-fed agriculture by 5% to 20%. Based on our interpretation, the commenter appears to take issue with the word "small" in the following IPCC finding: [e]levated CO_2 levels are expected to contribute to small beneficial impacts on crops. We note the preceding sentence indicates that there is still uncertainty about the sensitivity of crop yields in the United States and other world regions due to the direct effects of elevated CO_2 levels. Thus, the IPCC uses the qualifier word "small" because multiple factors other than the direct effects of CO_2 could lead to either positive or negative consequences for crop yields. We therefore disagree with the commenter that the TSD exhibits bias with respect to quantification of the relative positive and negative impacts on food production and agriculture. The TSD's summary of the projected positive and negative effects of climate change is accurate, balanced, and appropriately reflects the conclusions of the body of scientific literature.

See the Findings, Sections II.A.2, "Summary of Response to Key Legal Comments on the Interpretation of the Section 202(a) Endangerment and Cause or Contribute Test," and IV.B, "The Air Pollution Is

Reasonably Anticipated to Endanger Both Public Health and Welfare," for EPA's response to comments on the general issue of quantifying the relative impacts of climate change.

Comment (6-4):
Several commenters (3283.1, 3347.1, and 3747.1) indicate that a net detrimental effect is not apparent from freshwater and marine fisheries nor have these effects in some cases been quantified. One commenter notes the conclusion cited in the TSD that indicates that cold-water fisheries will be negatively affected; warm-water fisheries will generally benefit, and the results for cool-water fisheries are mixed.

Response (6-4):
The summary in the TSD does not draw any conclusions regarding "a net detrimental effect" for fisheries, but presents the balanced view that some fisheries may be adversely affected whereas others may benefit as a result of human-induced climate change.

Regarding quantification of effects, as described in the preceding response (6-3), the TSD summarizes both beneficial and adverse effects to fisheries from changes in climate and provides quantification when such information is available. See the Findings, Sections II.A.2, "Summary of Response to Key Legal Comments on the Interpretation of the Section 202(a) Endangerment and Cause or Contribute Test," and IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for EPA's response to comments on the general issue of quantifying the relative impacts of climate change.

Comment (6-5):
Several commenters (e.g., 0521, 0540, 0664, 0692, 0768.1, 1616.1, 2972.1, 3136.1, 3236.1, 3411.1, 3449.1, 3596.3, and 4032) indicate that the carbon cycle and increased levels of CO_2 in the atmosphere are and will continue to be beneficial for plant growth and agriculture. In support of this argument, the commenters make the following general assertions: (1) the carbon cycle in plants is a basic function for their survival and the majority of plant life prefers a much higher concentration of CO_2 than currently in our atmosphere; (2) essentially all important agricultural crops exhibit enhanced growth under both increased CO_2 concentrations and increased global temperatures; (3) CO_2 is not a pollutant, but a required ingredient for plant growth; (4) studies have shown that growth of plant life is accelerating with an increase in CO_2 in the environment.

Many commenters (e.g., 1594.1, 0540, 0664, 0692, 0768.1, 1616.1, 2972.1, 3136.1, 3236.1, 3411.1, 3449.1, 3596.3, 4032) also cite specific findings from the scientific literature as evidence of the beneficial effect of CO_2 on plants and crop production. Some commenters note Dr. Craig Idso of the Center for the Study of Carbon Dioxide and Global Change has provided extensive documentation of the benefits of CO_2 for plants, and at least one commenter submits a literature review by Dr. Idso, which the commenter claims provides scientific evidence of the beneficial effects of CO_2 on plants (e.g., plant growth, water-use efficiency, resilience to diseases, herbivores, and insects) and rebuts the TSD's conclusions that harm to agriculture is likely.

Response (6-5):
We do not dispute the fact that CO_2 (i.e., carbon) is a required ingredient for plant survival and growth, or that CO_2 can have a stimulatory effect on plant growth. This has been well known for quite some time. Sections 3, 9, and 10 of the TSD summarize the scientific assessment literature on the stimulatory or fertilization effect of CO_2 on plant growth and productivity. In addition, Section 9 of the TSD summarizes several findings from the assessment literature on overall plant growth in North America. The IPCC

(Field et al., 2007) cited a study by Nemani et al. (2003), which found that plant growth (measured by net primary productivity) increased from 1981 to 1998 across North America. See comment response (6-38) below for additional responses to comments on trends in net primary productivity.

We reviewed the studies submitted by commenters related to the direct effects (i.e., growth, water-use efficiency, photosynthetic rates, and productivity) of CO_2 on plants. Several of these same authors and studies are cited in the CCSP and IPCC reports. For example, the IPCC (Easterling et al., 2007) cites the work of Kimball et al. (2002) and the free-air CO_2 enrichment experiments on crop response. In addition, the IPCC (Field et al., 2007) cites the study by Idso et al. (1987), which shows increases on dry matter production with elevated temperature and CO_2, and the study by Woodward et al. (2004) regarding CO_2 stimulation of plant growth. Further, we note the CCSP (Hatfield et al., 2008) provides a comprehensive evaluation of Free-Air CO_2 enrichment (FACE) experiments studying crop response (e.g., photosynthesis, total biomass, grain yield, stomatal conductance, and evapotranspiration) to elevated CO_2 concentrations. Therefore, we conclude that these studies do not provide additional information not already summarized in Sections 3 and 9 of the TSD. Furthermore, not all studies that have examined the effects of elevated CO_2 concentrations on plant growth or crop productivity to date, including those submitted by commenters, have comprehensively included all relevant factors (e.g., CO_2 increases, temperature increases, precipitation changes, weather variability changes, ground-level ozone changes, soil nutrient changes), which is why, for this sector in particular, it is important for EPA to rely primarily on the assessment literature that brings many individual studies together in order to gain a more comprehensive view of the impacts of elevated CO_2 concentrations and climate change on United States agriculture.

Section 9 of the TSD summarizes the conclusions of the assessment literature that there is still uncertainty regarding overall crop sensitivity to elevated CO_2 levels when considered in light of other documented and projected climate impacts on agriculture. There, we summarize findings of the IPCC (Easterling et al. 2007), which provide scientific evidence that adverse effects on crop yields due to droughts and other extreme events may offset the beneficial direct effects of elevated CO_2 and moderate temperature increases in the near term. We describe the CCSP (Hatfield et al., 2008) finding that high temperatures, water and nutrient availability, extreme weather events (i.e., heavy downpours, droughts), enhanced pest and weed growth, and ozone exposure can significantly limit the benefits of the direct stimulatory CO_2 response on plant growth. In addition, we summarize the CCSP conclusion that as temperature rises beyond a certain threshold in the future, grain and oilseed crops will increasingly begin to experience failure, especially if climate variability increases and precipitation lessens or becomes more variable (Backund et al., 2008). In addition, CCSP concludes that the marketable yield of many horticultural crops (e.g., tomatoes, onions, fruits) is very likely to be more sensitive to climate change than grain and oilseed crops. Therefore, we disagree with the comment that all important agricultural crops exhibit and will continue to exhibit enhanced growth in the future under both increasing CO_2 concentrations and increasing global temperatures.

See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for EPA’s response to comments on the Administrator’s conclusions regarding the net effects of climate change on agriculture. See also Volume 1, Section 1.4, “Consideration of Net (Adverse and Beneficial) Effects,” for our response to comments on the general issue of evaluating net effects in the context of this action. Lastly, see Section III.A., “The Science on Which the Decisions Are Based,” for our response to comments on the use of the assessment literature and our treatment of new and additional scientific literature provided through the public comment process.

Comment (6-6):
Several commenters (e.g., 2972.1, 3136.1, 3347.1, 3394.1, 3596.2, 4003, and 11459) state that past and future technological improvements have and will continue to push agriculture to even higher production

yields despite the challenges that a changing climate may present. These commenters suggest that EPA must consider technological advances in assessing the scientific evidence for an endangerment finding. Commenters provide a report by Alan Carlin (Carlin, 2009) that indicates that the TSD is incomplete with regard to observed trends in agricultural productivity that show that, despite decades of increasing anthropogenic GHGs, crop yields have increased. As evidence of this positive trend in production yields, commenters submit the following information:

1) A commenter quotes the version of the TSD released with the Advance Notice of Proposed Rulemaking (ANPR): "For the past 30, 50, 100 years, agricultural yields have been increasing in the U.S., despite climate fluctuations and trends."
2) Commenters submit a figure depicting global average temperature and precipitation trends and corn and wheat yields over time (1895-2005) as evidence that crops yields have increased despite a variety of changes (climate, soil, and landscape, GHG levels, etc.).
3) A commenter submits a figure containing three maps of harvested acreage of major U.S. food crops (wheat, corn, and soybeans) as evidence that U.S. major cash crops are grown across a large range of climate conditions, indicating their adaptability to climate change.

At least one commenter states that although some more sensitive crops may be less productive under future climatic conditions, the U.S. agricultural and livestock industries are renowned for developing new strains and varieties of crops that prosper in different climatic conditions in the United States and throughout the world. Some commenters contend that herbicide-resistant and insect-resistant crop varieties help improve farmers' ability to control for insects and weeds, and state that this discussion is absent from the TSD Section 9(d). Another commenter argues that genetically engineered crop species will continue to improve farmers' ability to grow productive, healthy food crops in ample supply despite climate change effects, citing a reference from the Economic Research Service of the USDA on the widespread adoption of genetically engineered crops.

Response (6-6):

The commenters mention evidence of trends in observed increased productivity and refer to a number of technological improvements (e.g., genetically engineered crops) designed to reduce the impacts of climate change on agriculture. Regarding the potential for genetic selection or modification to alleviate climate change stressors on crops, Section 9 of the TSD states: "There are continual changes in the genetic resources of crop varieties and horticultural crops that will provide increases in yield due to increased resistance to water and pest stresses. These need to be considered in any future assessments of the climatic impacts; however, the genetic modifications have not altered the basic temperature response or CO_2 response of the biological system (Hatfield et al., 2008)." The scientific literature is clear that the possibility of changes in the genetic resources of crop varieties does not preclude evidence indicating vulnerability and impacts to the agricultural sector from climate change. See our responses to other comments in this section (e.g., 6-2, 6-5) for our response regarding the positive and negative effects of future climate change on agriculture.

With regard to the comment about considering technological advances in assessing the scientific evidence for an endangerment finding, see the Findings, Section IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

1) With regard to the statement quoted by the commenter from the version of the TSD released with the ANPR, we note that it was replaced by the discussion of crop yields and productivity in Section 9(a) of the April, 2009 version of the TSD, as well as the final TSD. To more accurately reflect the scientific assessment literature, the final TSD states: "Observational evidence shows that, over the last century, aggregate yields of major U.S. crops have been increasing (USDA,

2) We reviewed the submitted figures documenting higher production yields and harvested acreage over the last century and have determined that they are generally consistent with the underlying scientific literature of summarized in Section 9 of TSD. As indicated in the final TSD, observational evidence from Field et al. (2007) and USDA's 2007 report Crop Production Historical Track Records (USDA 2007) indicates that, over the last century, aggregate yields of major U.S. crops have been increasing, although with significant regional and temporal variation. We disagree, however, that past trends are indicative of future production trends under a changing climate. See our responses to other comments in this section (e.g., 6-2, 6-5) for our response regarding the positive and negative effects of future climate change on agriculture.

3) We note that agriculture in the United States is distributed across a range of climate conditions and note the distribution of crops and livestock. However, this does not preclude evidence indicating vulnerability of the agricultural sector to climate change. For example, increased climate variability or rapid changes in environmental conditions (i.e., extreme heat) can disrupt or reduce productivity regardless of climate conditions. See our responses to other comments in this section (e.g., 6-2, 6-5) for our response regarding the positive and negative effects of future climate change on agriculture.

Comment (6-7):
A commenter (3394.1) notes that the TSD indicates that human system responses to climate change are more difficult to identify and isolate due to the larger role that non-climate factors play (e.g., management practices in agriculture and forestry, and adaptation responses to protect human health against adverse climatic conditions). The commenter notes this is not mentioned in Section 9, nor does the TSD address these difficult uncertainties in its actual analysis of agricultural effects. The commenter states that it is unclear whether any of these considerations factored into EPA's assessment of this area of the science, and that accordingly, the proposed endangerment finding and the TSD fail to present a persuasive case in support of endangerment.

Response (6-7):
The science regarding the attribution of climate change to human activities is discussed in Section 5 of the TSD and our response to general comments on this issue is found in Volume 3 of this Response to Comments document. See Volume 1, Section 1.2 for our response to comments on the issue of differentiating between climate and non-climate drivers of impacts. We describe in Section 5(b) of the TSD the importance of considering climate variability and non-climate drivers (e.g., land-use change, habitat fragmentation) in order to make robust conclusions about the role of anthropogenic climate change in affecting biological and physical systems. Section 9 of the TSD discusses the number of ways in which crops, livestock, and fisheries may be affected by both elevated concentrations of CO_2 and resultant climate change, based on the underlying assessment literature on this topic. EPA therefore disagrees with the comment that our evaluation of the agricultural sector did not include the appropriate considerations.

See the Findings, Section IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

Comment (6-8):
A number of commenters (e.g., 0329, 0664, 0692, and 4032) argue that warmer temperatures and increasing CO_2 in the atmosphere may or will benefit agricultural production, food supply, and the prevention of widespread starvation due to longer growing seasons and CO_2 fertilization effects. The commenters ask if EPA considered the short- and long-term consequences to food supplies if GHGs, particularly CO_2 levels, are suppressed or even reduced to earlier levels.

In support of this argument, one commenter (0768.1) references a study by Nemani et al. (2003) on the increase in net primary production from 1982 to 1999; a USDA report with no citation documenting an increase in worldwide grain production to approximately 90 million tons between 1990 and 1999; and a United Nations Food and Agriculture Organization 2004 report presenting statistics on world mortality from malnutrition. The commenter attributes the crop production increases to rising CO_2 levels and temperatures and concludes that climate change will improve worldwide food production and decrease world mortality from starvation.

Response (6-8):
See Section 9 of the TSD and our responses to other comments in this section (e.g., 6-2, 6-5) for our response regarding the positive and negative effects of elevated CO_2 concentrations and climate change on agriculture and food supply. We reviewed the submitted figures documenting higher production yields and harvested acreage over the last century and determined that they are generally consistent with the underlying scientific literature summarized in Section 9 of TSD. As indicated in the final TSD, observational evidence from Field et al. (, which states: "Observational evidence shows that, over the last century, aggregate yields of major U.S. crops have been increasing (USDA, 2007; Field et al., 2007), with significant regional and temporal variations.." We do not find scientific support in the literature submitted for the commenter's claim that past trends are indicative of future production trends under a changing climate. Past trends reflect the impact of many variables in addition to climate, and the past impact of climate itself cannot be determined just by looking at the overall trend.

The endangerment analysis does not consider policies that would result in lowering atmospheric GHG concentrations to levels below current levels; nor does the endangerment analysis assess policy scenarios that would stabilize atmospheric GHG concentrations at some future level higher than today's. For our broader responses to these issues, see the Findings, Section III.C, "Adaptation and Mitigation." We reviewed the study by Nemani et al. (2003) and note the authors' findings of an increase in net primary productivity apply to vegetation of all types, and do not specifically address climate effects on crop species. In addition, the authors indicate the largest increase was in tropical ecosystems where Amazon rain forests accounted for 42% of the global increase in net primary production. Thus, we conclude this study does not address the regional variation and susceptibility of the U.S. agricultural sector to changes in climate.

Comment (6-9):
A commenter (3347.3) argues that the CCSP's conclusions in Backlund et al. (2008a) as summarized in the TSD are unreasonably pessimistic and over emphasize potential negative effects. The commenter states that the CCSP report's fundamental weakness is "a lack of significant consideration for the realization that agriculture is constantly changing, and farmers and their crops adapt to these changes."

The commenter makes the following points regarding specific CCSP conclusions summarized in TSD:

1. Contrary to the conclusions regarding increased future crop failure as temperature rises, the USDA Agricultural Projections to 2018 predicts a general increase in crop yield per acre through 2018. The commenter notes this includes projections for crops such as tomatoes, which are often

2. Contrary to the conclusions regarding the positive growth response of weeds to increasing CO_2, a study by Ziska (2003) found that the positive growth response of weed species to rising CO2 tapers off above a certain level.

3. Contrary to the conclusions regarding the future efficacy of glyphosate, the oft-cited study by Ziska and Goins (2006) does not obtain consistent results in all experimental trials of glyphosate; therefore, broad conclusions should not be drawn from this article.

4. Contrary to the conclusions regarding increasing disease pressure, pathogens, and parasites, and overall effects on livestock production, there are substantial plant and animal breeding industries that regularly develop new cultivars to thrive under new conditions (Troyer, 2004).

Response (6-9):

We have carefully reviewed the comments and we do not see any evidence that Backlund et al. (2008a), as summarized in the TSD, is unreasonably pessimistic with regard to adverse effects to food production and agriculture. Our responses to the commenter's specific points are as follows:

1. The USDA Agricultural Projections to 2018 predicts a general increase in crop yield per acre through 2018. According to the USDA information, these projections assume normal weather and no further outbreaks of plant or animal diseases. However, we find this projection to be consistent with the CCSP, which notes that overall, the benefits of increasing CO_2 concentrations over the next 30 years are projected to mostly offset the negative effects of temperature for most C3 crops, while the C4 crop yields are reduced by rising temperature (Hatfield et al., 2008). We note that the USDA projections cover a relatively short time frame (less than 10 years from present). In addition, regarding the commenter's assertion that estimates given by IPCC (Reilly et al., 2001) are far less negative than the discussion in the TSD, we find that the commenter bases this assertion on near-term estimates of benefits and does not comprehensively discuss all relevant factors (e.g., CO_2 increases, temperature increases, precipitation changes, weather variability changes, ground-level ozone changes, soil nutrient changes) in determining the overall risks and impacts to agriculture from climate change. Thus, EPA does not view the USDA projections or the commenter's claims regarding the Reilly et al. (2001) study as inclusive of the collective risks and impacts associated with climate change projected to occur over time (over the next few decades and out to 2100). See response (6-2) above for additional information on our response to comments regarding Reilly et al. (2001). Thus, for these reasons, we disagree with the commenter that CCSP and the TSD are overly pessimistic and find that they accurately reflect the findings of the assessment literature on the overall risks and impacts to agriculture from climate change.

2. Regarding the study referenced the commenter by Ziska (2003), we reviewed the study and note that it is consistent with research on the effect of climate change on competition between C3 and

3. Regarding the commenter's point related to glyophosate efficacy, EPA reviewed the study by Ziska and Goins (2006) and note the study is consistent with the interpretation of the CCSP and as reflected in the TSD. The authors note that, overall, the data suggest that, depending on weed species (C3 vs. C4), elevated CO_2 can increase weed biomass, decrease yields, and reduce glyphosate efficacy for Round-up Ready soybean (Ziska and Goins, 2006). In fact, we note this study was reconfirmed in the recent USGCRP report (Karl et al., 2009), which cites a recent study by Wolfe et al. (2007) that indicates future CO_2 levels impact the efficacy of weed control from this herbicide.

4. See the Findings, Section III.C, "Adaptation and Mitigation," for our response to comments on the treatment of adaptation and mitigation in the Findings.

Based on our review, we conclude that the findings of the CCSP 2008 report (Backlund et al., 2008a) are accurate and that the TSD's summary of positive and negative effects of climate change on agriculture was reasonable and appropriately reflects the conclusions of the body of scientific literature. Regarding the commenter's view that farmers and their crops will adapt to climate change, see the Findings, Section III.C, "Adaptation and Mitigation," for our response to comments on the treatment of adaptation and mitigation.

Comment (6-10):
One commenter (0591) notes that, in the past, CO_2 levels reached 1,000 parts per million (ppm) or greater. The commenter also states that temperatures during the Medieval Warm Period were significantly higher than they are now. The commenter states that since the Medieval Warm Period was one of the most flourishing times in human history, the likely benefits of climate change today include increasing crop yields in agriculture, barren lands becoming fertile, and warmer weather being easier to endure and more conducive to life than severe cold.

Response (6-10):
See Volume 4 of this Response to Comments document for EPA's responses to comments regarding current and past CO_2 levels in the atmosphere and temperatures during the Medieval Warm Period. The commenter provides no factual evidence upon which to base a conclusion that the Medieval Warm Period is analogous to present-day environmental conditions. The commenter provides no support for the assertions regarding increasing crop yields and barren lands becoming fertile. See our responses to other comments in this section regarding the effects of CO_2 on agriculture (both adverse and beneficial).

Comment (6-11):
In reference to the TSD's discussion of ground-level ozone effects on plant growth, one commenter (3411.1) states that, according to a study by Racherla and Adams (2006), climate change may actually reduce background levels of ozone, and, therefore, ozone would not greatly impact agricultural areas.

Response (6-11):
We have reviewed the reference submitted by the commenter and note that this study, as well as a more recent study by Racherla and Adams (2008), were evaluated in the EPA (2009a) report, which is cited extensively in Section 8 of the TSD. The Racherla and Adams (2008) study found that, while global near-surface tropospheric ozone is expected to decrease, summertime tropospheric ozone is expected to increase over North America. Section 8 of the TSD summarizes the following overall conclusions from the literature on this issue: (1) climate change is expected to decrease background ozone due to higher water vapor; (2) climate change is expected to increase regional and urban-scale ozone pollution due to higher temperatures and weaker air circulation; (3) ozone levels are expected to increase over substantial regions of the country at during summer months; and (4) the extent of changes in ozone levels in the future will vary at the regional and local level. Therefore, the TSD's discussion of impacts to agriculture from increased ozone exposure (e.g., limiting the benefits of direct stimulatory CO_2 response on plant growth) appropriately reflects the conclusions of the body of scientific literature.

Comment (6-12):
Commenters (3136.1, 3596.2) note that the TSD does not consider the implications of biofuel production on food and livestock production and assert that biofuels will be detrimental to the agricultural sector. A commenter (4032) indicates it is ironic that a contributing factor to the world's food shortage is the millions of acres of farmland converted from food crops to biofuels meant to stop global warming. At least one commenter expresses concern that the production of feed for livestock will be adversely impacted by increased ethanol production. Commenters state that the European Commission admitted that, to meet European Union's (EU) biofuel targets, they would eventually need almost all of the food-growing land in Europe. Two commenters (2972.1, 7037) submit a reference from Elock (2008) and the International Council for Science (2009) regarding biofuel production, which indicates the water requirements of biofuel-derived energy are 70 to 400 times larger than other energy sources such as fossil fuels, wind, or solar. Commenters also reference a study that indicates "The increase in corn production to support ethanol goals in the United States is predicted to increase nitrogen inputs to the Mississippi River by 37%" (Idso and Idso, 1994).

On the other hand, at least one commenter (1594.1) speaks on behalf of the positive effects of increasing CO_2 and indicates that rising atmospheric CO_2 levels are helping to increase grain production, which is beneficial to the United States biofuel program and will have a positive effect on public welfare.

Response (6-12):
These comments on biofuel production and agricultural food crops are not germane to the current endangerment and cause or contribute findings. Possible future policies or regulations related to alternative energy production or GHG mitigation approaches are outside the scope of this action. See Volume 11 of this Response to Comments document for our response to comments on the implications of the Findings for economic and related concerns.

Comment (6-13):
A commenter (3136.1) indicates that the TSD does not provide analysis of livestock production in the United States over the past few decades. In addition, at least two commenters (3136.1, 3347.3) reference a USDA Web site (http://www.ers.usda.gov/Briefing/baseline/livestock.htm) that provides agricultural baseline projections (2009 to 2018) for livestock and crop production. Another commenter disagrees that elevated CO_2 will decrease C4 grasses and decrease the nutritional value of forage for animals, which in turn affects animal weight and performance.

Response (6-13):
Section 9 of the TSD provides a summary of the vulnerability of the agricultural sector to climate change and how climate variability may affect U.S. food production and agriculture based on the conclusions of the scientific assessment literature. Past livestock production in the United States was reflected in the TSD in the context of observed and potential changes to productivity due to climate change. Regarding the referenced Web site, the commenter did not explain how an analysis of the livestock production in the United States over the past few decades or the USDA Web site on baseline livestock and crop production affect or alter the scientific findings summarized in the TSD. According to information on the USDA Web site, agricultural baseline projections are a neutral backdrop, or reference scenario, that provides a point of departure for discussion of alternative farm sector outcomes that could result under different domestic or international assumptions. These projections assume normal weather and no further outbreaks of plant or animal diseases. Thus, we have determined that these projections are not inclusive of the collective impacts associated with climate change projected to occur over much longer time-scales.

Regarding the question of whether elevated CO_2 will decrease C4 grasses and decrease the nutritional value of forage for animals, we note that the TSD does not state that forage quality will decrease. The TSD states there is limited information in the assessment literature regarding the specific effects on grasses and their nutritional quality. Section 9 of the TSD summarizes the IPCC (Easterling et al., 2007) and CCSP (Hatfield et al., 2009) conclusions that, based on expected vegetation changes and known environmental effects on forage protein, carbohydrate, and fiber contents, both positive and negative changes in forage quality are possible as a result of atmospheric and climatic change. Elevated CO_2 can increase the carbon-to-nitrogen ratio in forages and thus reduce the nutritional value of those grasses, which in turn affects animal weight and performance. Thus, we conclude that the TSD's summary of projected climate change effects on livestock appropriately reflects the conclusions of the body of scientific literature.

Comment (6-14):
Commenters (3136.1, 3596.3) mention that the EPA leaves out information in the TSD that certain plants exhibit increased water-use efficiency under elevated CO_2 conditions. Similarly, another commenter (3411.1) asserts that there is substantial observational evidence that the increased concentrations of atmospheric CO_2 have led to hardier growth and better water-use efficiency of vegetation in and around desert areas. The commenter cites various journal articles as supporting evidence for his assertion (e.g., Feng, 1999; Cheddadi et al., 2001; Eklundh and Olsson, 2003).

Response (6-14):
We have updated Sections 3 and 9 of the TSD to include information regarding the effect of elevated CO_2 levels on water-use efficiency and related biophysical processes in plants. We added to Section 3 a summary of the IPCC finding that increases in CO_2 affects water use and water-use efficiency of plants. According to IPCC (Hatfield et al., 2008), elevated CO_2 causes partial stomatal closure, which decreases conductance and reduces loss of water vapor from leaves to the atmosphere. Section 9 of the TSD describes the USGCRP conclusion that carbon dioxide makes some plants more water-use efficient and that this is a benefit in water-limited areas and in seasons with less than normal rainfall (Karl et al., 2009).

See previous comment responses in this volume for our response regarding the projected adverse and beneficial effects of climate change on plants.

Comment (6-15):

A commenter (2750) indicates that Section III.C.4 of the proposed action's preamble is confusing. Which is it: "increased rain and yields of rain-fed agriculture, or, precipitation lessens? And how exactly is an increase in aggregate yields of rain-fed crops a harm?"

Similarly, some commenters (3449.1, 3747.1) question the TSD's discussion of agricultural risks and impacts from projected precipitation changes given the large uncertainties about projecting future precipitation levels. One commenter contends that the TSD makes conflicting statements regarding precipitation—on one hand describing very large uncertainty about precipitation projections and on the other hand, stating that global mean precipitation is expected to increase in the future. In addition, the commenter states that the TSD statement that "grain and oilseed crops will increasingly begin to experience failure if climate variability increases and precipitation lessens or becomes more variable" conflicts with its description of an increase in global mean precipitation.

Response (6-15):

Regarding the language in Section III.C.4 in the Proposed Findings, it appears that the commenter has linked two separate and distinct statements together and misinterpreted them. To clarify, the assessment literature as summarized in the TSD concludes that while global mean precipitation is projected to increase, precipitation is expected to become more variable in both frequency and amount across different regions of the United States. This issue is discussed in Section 6 of the TSD and our responses to comments regarding future projections of precipitation trends are provided in Volume 4 of the Response to Comments document.

Section 9 of the TSD summarizes the scientific literature regarding the implications of precipitation changes on agriculture. It states: "Moderate climate change in the early decades of the century is projected to increase aggregate yields of rain-fed agriculture (water demand met primarily derived from precipitation) by 5 to 20%, but with important variability among regions. Future trends in precipitation are difficult to project but will be associated with strong regional and seasonal variation, which means some areas in the United States will continue to get wetter (e.g., Northeast and large parts of the Midwest) while some areas, particularly in the West, will become drier. Major challenges are projected for crops that are near the warm end of their suitable range or depend on highly utilized water resources [high confidence]." We therefore find no evidence that the TSD's discussion of the effects of precipitation changes on agriculture conflicts with the finding that global mean precipitation will increase.

In addition, Section 15 of the TSD summarizes the USGCRP's conclusions regarding regional precipitation patterns in the United States. The assessment literature concludes that although there is still considerable variation and difficulty predicting precipitation changes at smaller spatial scales, changes in precipitation patterns will play a large role in determining the net impacts of climate change. The IPCC (Field et al., 2007) concluded that agriculture in areas projected to experience decreased precipitation will be challenged by restricted availability of water for irrigation and at the same time increasing water demand for multiple uses, including for irrigated agriculture and human and ecological uses.

See the Findings, Section IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination in general, and with regard to the agricultural sector in particular.

Comment (6-16):

Two commenters (3449.1, 3747.1) question the EPA's conclusion of harm to agriculture from climate change by pointing to the fact that the TSD recognizes there is a lack of information on horticultural crops and CO_2 and few reliable crop simulation models for use in climate change assessments. The commenters conclude the evidence for impacts to agriculture from climate change is not strong enough to support an endangerment finding for public welfare.

Response (6-16):
Section 9 of the TSD summarizes the most recent body of scientific assessment literature regarding how observed and projected climate change may affect U.S. food production and agriculture as a whole. Projected climate impacts on horticultural crops are just one aspect of the observed and projected agricultural impacts from climate change summarized in the TSD. As the commenter notes, the discussion of horticultural crops in the TSD states that there are relatively few published studies quantifying horticultural crop response to CO_2 as compared to major grain and oilseed crops. However, the TSD also states that "The marketable yield of many horticultural crops is likely to be more sensitive to climate change than grain and oilseed crops because even short-term, minor environmental stresses can negatively affect visual and flavor quality (Hatfield et al., 2008)." We conclude that the TSD's discussion of agricultural risks and impacts accurately reflects the conclusions of the assessment literature.

See the Findings, Section IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination in general, and with regard to the agricultural sector in particular.

Comment (6-17):
One commenter (3475.1) states his support for the Findings, noting that California is particularly vulnerable to the impacts of climate change on agriculture, compared with the rest of the country. In support of this assertion, the commenter submits the following two papers from the California Climate Change Center as evidence that increasing drought and higher temperatures threaten agriculture in the state: Lobell and Field (2009), "California Perennial Crops in a Changing Climate," and Lee et al. (2009), "Effect of Climate Change on Field Crop Production in the Central Valley of California."

Response (6-17):
See Section III.A., "The Science on Which the Decisions Are Based," for our response to comments on the use of the assessment literature and our treatment of new and additional scientific literature provided through the public comment process. We reviewed the submitted articles on California crop productivity and determined that they are generally consistent with the underlying scientific literature as synthesized in Section 9 of TSD. Lobell and Field (2009) find that the direct effects of temperature and rainfall on perennial crop yields in California will vary, but that cherries and almonds are likely be the most negatively affected by warming over the next decades. Lee et al. (2009) find that in the latter half of the century, crop yields of alfalfa, cotton, maize, rice, sunflower, tomato, and wheat are likely to be negatively affected by climate change, particularly cotton and sunflower. These findings are consistent with Section 15 of the TSD, which summarizes the conclusions of the USGCRP (Karl et al., 2009) regarding regional impacts on agriculture and states, "Much of the region's agriculture may be negatively impacted by future warming, particularly specialty crops in California such as apricots, almonds, artichokes, figs, kiwis, olives, and walnuts."

Comment (6-18):
A commenter (9051.1) references several figures from a 2006 United Nations Environment Program report 2006 (Kandji, 2006) entitled "Climate Change and Variability in the Sahel Region: Impacts and Adaptation Strategies in the Agricultural Sector" as evidence that over the same period that CO_2 has supposedly been a "hazard," agricultural productivity, vegetation, and global carbon productivity in

Africa has been increasing. The commenter also quotes the report indicating that aggregate food production has increased in the Sahel and many other parts of sub-Saharan Africa since the early 1980s, primarily driven by the continued expansion of the cultivated areas. The commenter contends that, if anything, increased CO_2 is a benefit since it helps increase agricultural productivity and is definitely not a hazard to human health.

Response (6-18):
Section 9 of the TSD and our response to other comments in this volume summarize the most recent body of scientific assessment literature regarding how observed and projected climate change may affect U.S. food production and agriculture. The fact that agricultural productivity has increased in parts of sub-Saharan Africa does not preclude evidence indicating vulnerability and impacts to the U.S. agricultural sector from current and future climate change. The scientific literature is clear that the U.S. agricultural sector is experiencing the effects of, and will continue to be affected by, observed and future climate change. See our responses to other comments in this volume regarding specific projected positive and negative effects of future climate change on agriculture

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Comment (6-19):
A commenter (3136.1) indicates the TSD mentions how California wine grapes are currently near climate thresholds and are likely to experience decreases in yields. The commenter indicates that EPA did not mention Oregon wines and how they may fare in the future.

Response (6-19):
Section 9 of the TSD mentions California wine grapes as an example of a crop that is currently near a climate threshold (i.e., a temperature above which the crop will fail) and is likely to experience decreases in yields, quality, or both, even under moderate climate change scenarios. The commenter did not identify any supporting literature regarding climate change effects on Oregon wine grapes, nor did the commenter provide any evidence that including information about Oregon wine grapes would change the TSD's summary of the assessment literature's conclusions regarding projected climate impacts on crop yields and productivity.

Comment (6-20):
According to a commenter (1616.1), Section III.C.1 of the Proposed Findings indicates that stimulated growth of crops is one of the adverse effects of increased warming and $CO_{2.}$ The commenter finds it difficult to see why this is a problem.

Response (6-20):
EPA does not indicate that stimulated growth of crops due to elevated CO_2 concentrations is one of the adverse effects of increased CO_2 levels. See response (6-5) above for our response to comments regarding the direct stimulatory effects of elevated CO_2 levels. See Section IV.B of the Findings for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination in general, and with regard to the agricultural sector in particular.

Comment (6-21):
A commenter (10939) indicates deep concern about the impact that the climate crisis will have on the environment, his ranching operation, and our economy, and describes in detail changes indicative of climate change effects on his range and in southeastern Montana. The commenter has been following the scientific discussion on climate change, and attended lectures and conversations with Steve Running, a

climatologist based at the University of Montana in Missoula and member of the IPCC. According to Running, the climate in southeastern Montana is already getting more arid, and if things continue as observed, a half a foot more rain a year to grow the same crops currently grown would be necessary. The commenter describes the hardship in making a living in agriculture in eastern Montana and cannot imagine it would even be possible in 50 years, when the effects of climate change are more fully expressed.

Response (6-21):
EPA reviewed the commenter's observations about climate impacts in Montana and agrees that climate impacts are already occurring and will very likely continue to occur in the region. See Section 15 of the TSD for more information on agricultural impacts from climate change within the various regions of the United States. We also note that the TSD presents a synthesis of major assessment reports such as IPCC, and the work of Steve Running is represented in these reports.

Comment (6-22):
A commenter (3248) submits an article by Costello et al. (2009) entitled "Managing the Health Effects of Climate Change" as additional scientific evidence in support of the Proposed Findings.

Response (6-22):
We have reviewed the report and note that the information presented in Costello et al. (2009) with regard to food production and agriculture is generally consistent with or in some cases cite the same scientific assessments (Field et al., 2007) summarized in the TSD. Costello et al. (2009) find that "although agricultural productivity might increase in some regions as a result of global warming (almost entirely in the rich high-latitude countries, although Sahara greening might benefit west Africa), increases in extreme weather (e.g., drought, wildfire, flooding) events may damage crops and disrupt farming." This is generally consistent with Section 9(c) of the TSD, which focuses on the United States and summarizes the literature regarding the adverse effects on crop yields due to droughts and other extreme events, which may offset the potential beneficial effects of elevated CO_2, moderate temperature increases over the near term, and longer grower seasons.

Comment (6-23):
Many commenters (e.g., 0362, 0731, 1807, 3383.1, 3642, 4184, 4249, 9786, and 10838) state their support for the Findings and describe various adverse effects that global warming will likely have on food production. According to the commenters, these include decreased crop yields, decreased food supply, increased application of pesticides, rising food costs and food shortages, and in worst case, famines. Some commenters (0725, 0803.1, 1318.1, 1543, 3104, 3601.1, 8516, and 8874) identify the following threats to food supply: (1) the impact of increasing ocean acidity and the collapse of marine ecosystems on fisheries; (2) crop impacts due to increasing viability of invasive pests; (3) impact of heat stress on farm animals and trees, which will decrease milk and maple syrup production; and (4) impacts of more intense periods of spring rain and flooding, along with longer summer droughts, on agriculture. A commenter (3400.1) from Washington State mentions that he is seeing increased water stress on agriculture. Some commenters (e.g., 3421, 4748, and 6894) express concern about the effects of extreme weather such as heat waves, droughts, floods, wildfires, and hurricanes have had or would have on the farming and fishing industries.

Response (6-23):
We reviewed the comments provided and note they are generally consistent with the discussion of climate impacts on agriculture in Section 9 of the TSD, which summarizes the literature regarding the effects of climate change and associated changes in the frequency and magnitude of extreme events and

disturbances (i.e., extreme heat, droughts, wildfires, and insect pests) on crop yields, freshwater and marine fisheries, and livestock.

6.2 Forestry

Comment (6-24):
Several commenters (e.g., 3136.1, 3449.1, 3447.3, 3747.1, and 11166) state that specific aspects of the climate impacts evidence summarized in the TSD with respect to forestry do not support the Administrator's endangerment finding.

Response (6-24):
The specific issues that underlie these comments are addressed in the responses throughout this volume, and other volumes of the Response to Comments document. With regard to the commenters' conclusion that the current science does not support an endangerment finding with respect to forestry, we disagree based on the scientific evidence before the Administrator. See the Findings, Section IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for details on how the Administrator weighed the scientific evidence underlying her endangerment determination in general, and with regard to the forestry sector in particular.

Comment (6-25):
A commenter (11453.1) submits a petition for EPA to resolve any dispute concerning the impact of elevated greenhouse gases on crop yields and forest growth to permit parties to present evidence supporting their conclusions, and to permit cross-examination of the competing experts offering that evidence. Absent such an approach, EPA cannot properly give credence to the vague claims of those who support a positive endangerment finding concerning crop yields and forest growth. The commenter claims the evidence supports the view that climate change has a net beneficial impact on forests.

Response(6-25):
See Section I.C.3.e of the Findings for our response to the request to hold formal proceedings on the scientific evidence. See our responses to other comments in this section regarding the beneficial and adverse effects of climate change on U.S. forestry.

Comment (6-26):
Several commenters (e.g., 2750, 3136.1, 3347.1, 3394.1, 3449.1, 3722, 3747.1, and 7037) request clarification of or question what they believe to be EPA's conclusions regarding the net effects of climate change on forestry (i.e., if EPA is concluding that the positive effects of climate change on forestry will ultimately be outweighed by negative effects or vice versa). For example, a commenter (2750) notes that EPA should explain how global warming conditions will lead to increases in wildfires and droughts yet overall forest growth will increase, as described in the TSD. Another commenter indicates that specific findings of climate change effects that may occur in some parts of the U.S. forestry sector do not provide sufficient information to judge the overall consequences and risks to U.S. forestry posed by greenhouse gases. The commenter states that the information presented in the TSD regarding forestry benefits resulting from climate change do not support the Administrator's endangerment finding.

Many commenters state that elevated CO_2 levels and warming temperatures have produced and will continue to produce benefits for society, such as promoting increased plant and vegetation growth, forest products, and carbon storage capacity. Some commenters note there are numerous examples of forestry benefits cited in the TSD and conclude that the positive benefits of climate change on forestry will outweigh any adverse effects. At least one commenter (3596.3) provides a literature review by Dr. Craig Idso of the Center for the Study of Carbon Dioxide regarding studies that the commenter asserts provide evidence not cited in the TSD of the positive benefits of elevated CO_2 levels on plants. The commenter states that this literature provides scientific evidence that increasing atmospheric CO_2 levels will increase plant (including tree species) productivity, water-use efficiency, resistance and resilience to disease, while reducing adverse effects of insect pest herbivory.

Response (6-26):
Section 10 of the TSD summarizes the findings of the assessment literature regarding both the adverse and beneficial impacts of climate change on the forestry sector. Here, we will first discuss the commenters' concerns with respect to the TSD's characterization of the science regarding the net effects of climate change on forestry, and then address the request for clarification regarding how the Administrator weighed the evidence.

The assessment reports indicate that climate change can in some cases have a beneficial impact on forest growth and productivity. However, commenters fail to take account the variation in the impact climate change can have on forests and the source of this variation. Forests are complex, varied, and dynamic ecosystems, and there are many ways in which climate change can impact the circumstances relevant to the health of the widely differing forest ecosystems. As such, it is a serious oversimplification to conclude that climate change or increased CO_2 concentration and temperature will result in increased growth or productivity of a forest. The diversity of forest ecosystems and the many ways in which climate change affects the environment of a forest mean there is not a single or simple answer to the question of how climate may impact forest growth, productivity, and overall health. The TSD and the underlying assessment reports reflect this complexity and provide a sound basis for assessing the varying impacts of climate change on forestry.

The assessment literature recognizes the potential in the near term for increased forest growth and productivity in certain areas of the country. Increased CO_2 concentrations can have a fertilizing effect, as rising CO_2 will very likely increase photosynthesis for forests. However, the increased photosynthesis will likely only increase wood production in young forests on fertile soils, and new studies suggest that direct CO_2 effects on tree growth may be lower than previously assumed (Easterling et al., 2007). Additionally, the initial increase in growth increments may be limited by competition, disturbance, air pollutants (primarily tropospheric ozone), nutrient limitations, ecological processes, and other factors, and the response is site- and species-specific (Easterling et al., 2007). The areas where forest growth increases could occur include areas where water is not an otherwise limiting factor. Nitrogen deposition and warmer temperatures have very likely increased forest growth broadly where water is not limiting and will continue to do so in the near future. Forest growth from climate change can also occur in regions where tree growth has historically been limited by low temperatures and short growing seasons, with climate change leading to increased temperature and longer growing season. However, increased growth in some areas or species can be at the expense of other species. Mountain forests are increasingly encroached upon from other species native to adjacent lowlands, while simultaneously losing high altitude habitats due to warming (Fischlin et al., 2007). For example, in Colorado, aspen have advanced into the more cold-tolerant spruce-fir forests over the past 100 years.

Climate change, particularly changes in precipitation patterns and extreme weather events, can also adversely impact forest growth and productivity. As summarized in Section 10 of the TSD, the IPCC (Field et al., 2007) concluded that forest growth is slowing in areas subject to drought. For example, on dry south-facing slopes in Alaska, growth of white spruce has decreased over the last 90 years, due to increased drought stress. A combination of warmer temperatures and insect infestations has resulted in economically significant losses of the forest resource base in Alaska (Field et al., 2007). In semi-arid forests of the southwestern United States, growth rates have decreased since 1895, correlated with drought from warming temperatures (Field et al., 2007).

Forests are also significantly impacted by disturbances such as drought, storms, insect outbreaks, and wildfire. While in some cases a changing climate may have positive impacts on the productivity of forest systems, changes in disturbance patterns are expected to have a substantial impact on overall gains or losses. Wildfires and droughts, among other extreme events (e.g., hurricanes) that can cause forest damage, pose the largest threats over time to forest ecosystems. A climate-change-related increase in frequency or intensity of such disturbances is at least as important to ecosystem function as incremental changes in temperature, precipitation, atmospheric CO_2 concentration, nitrogen deposition, and ozone pollution.

As summarized in Section 10 of the TSD, disturbances partially or completely change forest ecosystem structure and species composition, cause short-term productivity and carbon storage loss, allow better opportunities for invasive species to become established, and command more public and management attention and resources. Climate change has very likely increased the size and number of forest fires, insect outbreaks, and tree mortality in the interior West, the Southwest, and Alaska, and will continue to do so. Several lines of evidence suggest that large, stand-replacing wildfires will likely increase in frequency over the next several decades because of climate warming (Ryan et al., 2008). General climate warming encourages wildfires by extending the summer period that dries fuels, promoting easier ignition and faster spread (Field et al., 2007).

Following the assessment literature, the TSD also describes that insects and diseases are a natural part of forested ecosystems and outbreaks often have complex causes. The effects of insects and diseases can vary from defoliation and retarded growth, to timber damage, to wide-scale forest diebacks. For example, during the 1990s, Alaska's Kenai Peninsula experienced an outbreak of spruce bark beetle over 6,200 square miles (16,000 km^2) with 10% to 20% tree mortality (Anisimov et al., 2007). In addition, the TSD summarizes the following conclusions of the CCSP (Ryan et al., 2008) that 1) the ranges of the mountain pine beetle and southern pine beetle are projected to expand northward as a result of average temperature increases, and 2) increased probability of spruce beetle outbreak as well as increase in climate suitability for mountain pine beetle attack in high-elevation ecosystems has also been projected in response to warming. Insect life cycles, which are sensitive to climate change, can also be a factor in pest outbreaks. The assessment literature notes that many northern insects have a two-year life cycle, and warmer winter temperatures allow a larger fraction of overwintering larvae to survive. Recent warming trends in the United States have led to earlier spring activity of insects and proliferation of some species, such as the mountain pine beetle (Easterling et al., 2007). Climate change may also indirectly affect insect outbreaks by affecting the overall health and productivity of trees. For example, susceptibility of trees to insects is increased when multiyear droughts degrade the trees' ability to generate defensive chemicals (Field, et al., 2007). Warmer temperatures have already enhanced the opportunities for insect spread across the landscape in the United States and other world regions (Easterling et al., 2007). Climate change can shift the current boundaries of insects and pathogens and modify tree physiology and tree defense. An increase in climate extremes may also promote plant disease and pest outbreaks (Easterling et al., 2007).

The impacts on a forest ecosystem from drought, storms, insect outbreaks, and wildfire are serious and can be very significant. Over a short period of time they can lead to dramatic and fundamental adverse changes in the health of the forest ecosystem, in contrast to the incremental, slow, and limited beneficial effect to forest growth that can occur in some areas and forests.

Regarding the literature submitted by commenters, we find that these studies have not comprehensively included all relevant factors (e.g., CO_2 increases, temperature increases, precipitation changes, weather variability changes, ground-level ozone changes, soil nutrient changes) for assessing the overall effect of climate change on forestry. For this reason, it is important for EPA to rely primarily on the assessment literature, which integrates and synthesizes the results of many studies across multiple relevant disciplines in order to gain a more comprehensive view of the impacts of elevated CO_2 concentrations and climate change on U.S. forestry.

Regarding the specific comment on the dual effects of increased productivity under some circumstances and increased wildfires under others, we do not view these effects as inconsistent with the underlying science. The effect of gradual increases in productivity due to rising CO_2 atmospheric concentrations and modest average temperature increases can be thought of as a change in average conditions, whereas the effect of increased risk of wildfires can be thought of as episodic events—the frequency and severity of which are altered by changes in underlying average conditions; therefore, these effects can coexist. Due to regional differences, where some regions are already more susceptible to wildfires, it is also possible to have both increases in wildfires in some regions yet overall increases in productivity in other regions, depending on local conditions and the rate and magnitude of climate change. Importantly, we note Field et al. (2007) indicates that the increase in overall forest growth will not be uniform, and that the effects of disturbances such as wildfire, insect outbreaks, and drought will also have regional variability.

Regarding the comment that some impacts may occur in some parts of the United States and not others, additional regional information has now been brought into the TSD. Specifically, we included conclusions from the latest assessment from USGCRP, which reports that certain regions of the United States will be particularly susceptible to increased wildfire, including Alaska and the western United States (Karl et al., 2009). Changes in precipitation and weather extremes are also important considerations, accounting for part of the regional variability in forest response (Easterling et al., 2007). The CCSP (Ryan et al. 2008) concludes that forest productivity varies with annual precipitation across broad gradients and with interannual variability within sites. They state that if existing trends in precipitation continue:

> Forest productivity will likely decrease in the interior West, the Southwest, eastern portions of the Southeast, and Alaska.
> Forest productivity will likely increase in the northeastern United States, the Lake States, and in western portions of the Southeast.
> An increase in drought events will very likely reduce forest productivity wherever these events occur.

We disagree with the comments that the existence of benefits or potential for benefits as a result of elevated CO_2 concentrations and climate change does not allow for the conclusion that the evidence, when viewed in its entirety, shows current adverse effects and the potential for increasing risks. We have provided further clarification of the Administrator's consideration of the forestry sector for the endangerment to public welfare finding in Section IV.B.2 of the Findings. See also Volume 1, Section 1.4, "Consideration of Net (Adverse and Beneficial) Effects," for our response to comments on the general issue of evaluating net effects in the context of this action.

Comment (6-27):

A commenter (3722) states that as forests grow and expand their ranges, they sequester ever larger quantities of carbon, which helps reduce increasing concentrations of atmospheric CO_2. As supporting evidence, the commenter cites information from a NASA Web site stating that "vast vegetated areas of the Northern Hemisphere, primarily from the boreal and temperate forests of North America and Eurasia, have been consuming and storing about one-quarter of CO_2 emissions during the past 15 years." Another commenter (3394.1) indicates that EPA ignores a singular benefit of increased forest growth: the correlated increase in CO_2 sinks. The commenter notes that neglecting these complex interactions skews the analysis of endangerment from GHG emissions and likewise feeds into what most likely are inaccurate projections of future GHG concentrations.

Response (6-27):
EPA does not ignore the effects of carbon sequestration in forests, and Section 10(a) of the TSD clearly acknowledges that forest productivity has increased in the United States since the middle of the 20th century. The purpose of the TSD, however, is to summarize the scientific assessment literature regarding how climate change and elevated CO_2 may impact forests. Thus, the TSD describes the scientific findings with respect to forest productivity (Section 10[a]), wildfire and drought risk (Section 10[b]), forest composition (Section 10[c]), and insects and diseases (Section 10[d]). In each of these sections, the recent findings of the assessment literature are summarized, including both adverse and beneficial impacts and discussion of uncertainties.

As summarized by the TSD, the literature indicates that there will be both gains and losses in carbon storage in U.S. forests as a result of climate change. How these changes in forest carbon, or more broadly in terrestrial ecosystem carbon, will act as either positive or negative feedbacks under climate change are generally taken into account in the future projections of climate change in the TSD. Response to comments on this latter issue is addressed in Volume 4 of this Response to Comments document, wherein we note that Meehl (2007) found "unanimous agreement among the coupled climate carbon cycle models driven by emission scenarios run so far that future climate change would reduce the efficiency of the Earth system (land and ocean) to absorb anthropogenic CO_2. As a result, an increasingly large fraction of anthropogenic CO_2 would stay airborne in the atmosphere under a warmer climate."

Comment (6-28):
A commenter (1594.1) indicates IPCC relies on predictions from models rather than factual scientific studies to evaluate impacts to forestry. The commenter contends that global warming and rising atmospheric CO_2 levels have and will continue to benefit plant/vegetation growth, and that these benefits dwarf any adverse effects otherwise affecting humans. The commenter indicates there is abundant evidence to support this whereas factual evidence is lacking for the adverse effects. The commenter indicates that forests become more productive and create more biomass as a result of rising CO_2 levels in the atmosphere. As supporting evidence, the commenter submits a scientific journal article by Norby et al. (2005) that finds that elevated CO_2 levels resulted in a 23% increase in forest productivity within the study area. The commenter notes these are actual field studies, not computer model simulations.

Response (6-28):
The commenter's assertion that the IPCC and TSD rely solely on computer model simulations is incorrect. The TSD summarizes the latest conclusions of the assessment literature on climate change effects on forest productivity and growth from experimental field studies, observations data, and modeled projections. The TSD notes the general findings from a number of recent syntheses using data from FACE study sites that show North American forests will absorb more CO_2 and might retain more carbon as atmospheric CO_2 increases. Included in this series of studies is Norby et al. (2005), which the commenter references. Furthermore, the TSD also summarizes a number of studies reported by the IPCC (Field et al., 2007) that demonstrate (based on observed data) the connection between changes in U.S. forest growth and climate variables.

As summarized in the TSD, in some areas, forest productivity will likely decrease due to increased increase climate variability and increases in disturbances (e.g., droughts, wildfires, pest outbreaks). In other words, the beneficial impact of elevated CO_2 on forest growth and productivity is only one of the possible effects of climate change on forests. As addressed in the assessment literature and summarized in the TSD, drought, pests, and wildfires will also affect growth and productivity. Further, forest productivity is known to be sensitive to changes in climate variables that may be modulated where water is limiting (Ryan et al., 2008). Similarly, the TSD also notes that young forests on fertile soils will achieve higher productivity from elevated atmospheric CO_2 concentrations whereas older forests may not (Ryan et al., 2008). Therefore, the effects of productivity will not be uniform and will vary significantly by region. The commenter has not provided scientific evidence to support the assertion that the beneficial impacts of elevated CO_2 on plant growth and productivity will "dwarf" the adverse effects. The assessment literature clearly indicates that the picture is much more complex, and the TSD accurately describes the multiple effects climate change may have on forests.

Comment (6-29):
Commenters (3347.1, 3347.3, and 3394.1) indicate that the Administrator fails to account for all of the benefits of climate change listed in the TSD in Section 10(a), and ignores the benefit of carbon sink potential with increased forest growth. A commenter (3347.3) indicates that the EPA does not present or consider the carbon storage potential associated with an increase in forest growth of 10% to 20%. The commenter indicates that the tone of the TSD ignores the scale of the net carbon sink of forests (some 256 million tons of carbon [1 billion tons of CO_2 per year]) as provided by King et al. (2008) and those provided provide by Joyce et al. (2001).

Response (6-29):
See the Findings, Section IV.B.2, for a description of how the Administrator evaluated the adverse and beneficial impacts of climate change on forests. In response to comments, this section was expanded and provides additional detail as compared to the Proposed Findings. See also Volume 1, Section 1.4, "Consideration of Net (Adverse and Beneficial) Effects," for our response to comments on the general issue of evaluating net effects in the context of this action. See our response above (6-27) on the issue of the treatment of carbon storage potential in the Findings and in the underlying science summarized in the TSD.

Comment (6-30):
A commenter (3136.1) indicates that the TSD notes that "Bioclimatic modeling…suggests that, over the next century, tree species richness will decrease in most parts of the coterminous United States even though long-term trends (millennia) ultimately favor increased richness in some locations." The commenter notes that, on the whole, there is no quantitative analysis given of the net change in richness, and therefore no support for the Proposed Findings. Another commenter (7020) indicates that the sections on forest productivity, wildfire and drought, forest composition, and insects and diseases need to be improved to quantify the impacts and risks.

Response (6-30):
With respect to tree species richness, the TSD reflects the state of scientific research and knowledge on this topic based on the major scientific assessment reports. We recognize that there is limited information on quantitative projections of species richness over the full range of tree species types. Section 15 of the TSD notes, "In the United States, some common forest types are projected to expand, such as oak-hickory; others are projected to contract, such as maple-beech-birch. Still others, such as spruce-fir, are likely to disappear from the contiguous United States (Karl et al., 2009)." The TSD reports the most recent findings (both qualitative and quantitative) from the scientific assessment literature indicating how distributions of tree species and forest composition may shift or be modified as a result of climate change. Examples of where the TSD summarizes the scientific literature with quantitative estimates and uncertainty where available are included are provided below. The commenters' contention that there is

"no quantitative analysis" is incorrect. Where quantitative information is available in the underlying literature, we have summarized it in the TSD. We note the commenters do not provide additional scientific literature on these issues.

In Section 10(b) on forest productivity, the TSD notes:

> Overall forest growth in North America will likely increase modestly (10% to 20%) as a result of extended growing seasons and elevated CO_2 over the next century but with important spatial and temporal variation.
>
> Forest growth appears to be slowly accelerating (less than 1% per decade) in regions where tree growth has historically been limited by low temperatures and short growing seasons.
>
> The length of the vegetation growing season has increased an average of two days per decade since 1950 in the conterminous United States, with most of the increase resulting from earlier spring warming.

In Section 10(b) on wildfire and drought, the TSD notes:

> Since 1980, an average of about 22,000 km^2/year (8,500 mi^2/year) has burned in wildfires, almost twice the 1920-1980 average of about 13,000 km^2/year (5,020 mi^2/year).
>
> The forested area burned in the western United States from 1987-2003 is 6.7 times the area burned from 1970-1986.
>
> Disturbances such as wildfire and insect outbreaks are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons (very high confidence)**.**[1]
>
> Earlier spring snowmelt has led to longer growing seasons and drought, especially at higher elevations, where the increase in wildfire activity has been greatest.
>
> In the southwestern United States, fire activity is correlated with El Niño-Southern Oscillation (ENSO) positive phases (La Niña) and higher Palmer Drought Severity Indices. El Niño events tend to bring wetter conditions to the southwest, enhancing the production of fine fuels and, La Niña events tend to bring drier conditions. Major fire years tend to follow the switching from El Niño to La Niña conditions due to buildup of material during wet years followed by desiccation during a dry year, whereas small fires are strongly associated directly with previous year's drought. Other modes of atmospheric and oceanic variability are known to impact temperature and precipitation (Gutowski et al., 2008) and hence wildfire patterns and activity.

In Section 10(c) on forest composition the TSD notes:

> Aerial photographs show increased shrub abundance in 70% of 200 locations.
>
> Along the Arctic to sub-Arctic boundary, the tree-line has moved about 6 mi (10 km) northwards, and 2% of Alaskan tundra on the Seward Peninsula has been displaced by forest in the past 50 years.
>
> The pattern of northward and upward tree-line advances is comparable with earlier Holocene changes.
>
> Analyses of satellite images indicate that the length of growing season is increasing by three days per decade in Alaska.

Furthermore, the TSD notes that evidence of shifts in tree species has been observed in the Green Mountains of Vermont where temperatures have risen 2°F to 4°F (4°C to 7 C) in the last 40 years and the

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[1] According to IPCC terminology, "very high confidence" conveys a 9 out of 10 chance of being correct. See Box 1.2 for a full description of IPCC's uncertainty terms.

ranges of some mountain tree species in this region have shifted to higher elevations by 350 feet (107 m) in the last 40 years. Tree communities were relatively unchanged at low and high elevations but in mid-elevation transition zones, the changes have been dramatic. Tree species suited to cold conditions in the Green Mountains declined from 43% to 18% while species suited to warmer conditions increased from 57% to 82%.

In Section 10(d) on insects and diseases, the TSD notes that recent warming trends in the United States have led to earlier spring activity of insects and proliferation of some species, such as the mountain pine beetle (Easterling et al., 2007). During the 1990s, Alaska's Kenai Peninsula experienced an outbreak of spruce bark beetle over 6,200 square miles (16,000 km^2) with 10% to 20% tree mortality (Anisimov et al., 2007).

See the Findings, Sections II.A.2, "Summary of Response to Key Legal Comments on the Interpretation of the Section 202(a) Endangerment and Cause or Contribute Test," and IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for EPA's response to comments on the general issue of quantifying the relative impacts of climate change.

Comment (6-31):
Several commenters (2972.1, 3136.1, 3596.2, 3722, and 7037) argue that large-scale circulation patterns and natural climate variations that occur over multiple decades (i.e., the Atlantic Multi-Decadal Oscillation (AMO), ENSO, and Pacific Decadal Oscillation (PDO))—are the primary drivers for wildfires and drought in the western United States rather than anthropogenic climate change. Another commenter argues that patterns in wildfires and drought frequency are a complex interplay between forest management practices, natural climate oscillations, and anthropogenic climate change, and that the TSD fails to take these issues into account. A commenter (2972.1) suggests that this indicates that it remains uncertain that wildfires will be more likely in the future.

In addition, the commenters describe findings from the following studies, which they claim provide supporting scientific evidence for their argument.

> Schoennagle et al. (2005) conclude that ENSO and PDO variability affect drought-induced fire occurrence in the Rocky Mountain subalpine forests. There remains considerable uncertainty regarding the effects of CO_2-induced warming at regional scales.
> Westerling and Swetnam (2003) conclude that drought and wildfire are associated with warm phases of ENSO and PDO in the Pacific Northwest and northern Rockies while the opposite occurs in the Southwest and southern Rockies.
> McCabe et al. (2004) conclude that wildfire patterns across the United States involve complex interactions with local and regional climate related to sea surface patterns in both the Pacific and Atlantic Oceans that are primarily driven by natural oscillations such as the PDO and the AMO. Drought and wildfire are associated with warm phases of ENSO and PDO in the Pacific Northwest and northern Rockies, while the opposite occurs in the Southwest and southern Rockies.
> Riano et al. (2007) conclude that there was no significant global annual upward or downward trend in burned area between 1981 and 2000 using NOAA-NASA Pathfinder and latitude was not determinative, as divergent fire patterns were encountered for various land cover areas at the same latitude.
> Kitzberger et al. (2007) conclude that sea surface temperature variability in the Pacific and Atlantic oceans (such as those associated with ENSO, PDO, and AMO) is a dominant factor in whether wildfires are widespread across the West, including recent wildfires. The key issue is that

Zhang et al. (2008) offer further evidence that the AMO cycles are driven by natural, rather than anthropogenic, forces as we are currently in the warm phase of the AMO and, given the very long-term nature of this Atlantic Ocean/climate phenomenon, we are likely to be in the AMO warm phase for quite some time to come.

Response (6-31):
See Volume 3 for EPA's responses to comments broadly focused on the extent to which observed climate change can be attributed to the observed increase in atmospheric GHG concentrations. See Volume 2 for EPA's responses to comments on observed changes in extreme events and precipitation. Here, we concentrate on the issues raised by the commenters on the effect of large-scale circulation patterns and natural climate variations on wildfires and drought in the western United States.S and the extent to which they are related.

The scientific assessment literature summarized in the TSD supports the view that wildfire and drought patterns are a complex interplay between forest management practices, natural climate oscillations, and anthropogenic climate change. The TSD does not state that anthropogenic climate change is the primary driver of wildfire patterns; rather, the discussion in Section 10 of the TSD indicates that wildfire patterns involve multiple influencing factors but, despite these complicated relationships, there remains evidence that climate change has likely influenced forest fires in some regions and will continue to do so**.** With respect to the influence of natural climate variations such as the AMO, ENSO, and PDO on wildfire, the TSD includes the following IPCC conclusions (Easterling et al., 2007; Field et al., 2007): (1) ENSO events are likely to intensify with climate change, with subsequent changes in vegetation and water availability; (2) in the southwestern United States, fire activity is correlated with ENSO positive phases and higher Palmer Drought Severity Indices; and (3) higher temperatures in the future will likely extend fire seasons throughout the western United States, with more fires occurring earlier and later than is currently typical, increasing the total area burned in some regions. We have revised Section 10(b) of the final TSD to provide further clarification on climate variability and the relationship between fire activity and natural climate variations.

We disagree with the commenters' assertion that anthropogenic climate change is not a significant influence with respect to the frequency and intensity of wildfires and drought in the western United States..In addition, we disagree with the comment that it remains uncertain that climate change can increase wildfire frequency and severity in the future. The TSD notes multiple lines of evidence that link warming temperatures and other climate change effects (i.e., longer summer season, timing of snowmelt) to an increased probability and risk of wildfires and wildfire frequency. As summarized in the TSD, the IPCC concludes that large, stand-replacing wildfires will likely increase in frequency over the next several decades because of climate warming (Ryan et al., 2008). The TSD specifically notes that general climate warming encourages wildfires by extending the summer period that dries fuels, promoting easier ignition and faster spread. With regard to certainty, the IPCC (Field et al., 2007) concludes with very high confidence that disturbances such as wildfire and insect outbreaks are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons.

Climate change effects on the frequency and severity of wildfires will vary by region. Nevertheless, the assessment literature as summarized in the TSD concludes that, "Climate change has very likely increased the size and number of forest fires, insect outbreaks, and tree mortality in the interior West, the Southwest, and Alaska, and will continue to do so." The TSD also includes the following conclusions from the IPCC and USGCRP:

Evidence indicates that since 1980, an average of about 22,000 km^2/year has burned in wildfires in the United States, almost twice the 1920-1980 average of about 13,000 km^2/year (Field et al., 2007).
Wildfires are projected to increase, especially in the Southwest (Karl et al., 2009).
Alaska has experienced large increases in fire, with the area burned more than doubling in recent decades, and as in the western United States, higher air temperature is a key factor (Karl et al., 2009).

We reviewed the submitted articles, and our responses to each of the specific studies are as follows:

Regarding the Schoennagle et al. (2005) study, we find that this paper is generally consistent with the underlying scientific literature summarized in Section 10 of the TSD, which states that there are multiple influencing factors (e.g., forest management practices, natural climate variations, and climate change) on wildfire patterns.
Regarding the Westerling and Swetnam (2003) study, we find that this paper is generally consistent with the underlying scientific literature summarized in Section 10 of the TSD, which states that there are multiple influencing factors (e.g., forest management practices, natural climate variations, and climate change) on wildfire patterns and which reports that in the southwestern United States, fire activity is correlated with ENSO positive phases (La Niña) and higher Palmer Drought Severity Indices (Field et al., 2007).
Regarding the McCabe et al. (2004) study, we note that, although the study found that the AMO and PDO likely have important influences on changes in drought frequency, the study also found that one component of the temporal pattern in drought matched well with the trends in Northern Hemisphere temperatures. The component that matched well with temperature trends, and which therefore might be an indicator of how patterns of drought might respond to continued increasing global average temperatures, included increasing drought in locations such as California and the northern Rockies, but decreasing drought in locations such as the Gulf Coast and the Pacific Northwest. We note this is generally consistent with the underlying scientific literature of the TSD as summarized in Section 10, which states that there are multiple influencing factors (e.g., forest management practices, natural climate variations, and climate change) on wildfire patterns. Therefore, we find no evidence that this study contradicts the IPCC conclusion summarized in the TSD that large, stand-replacing wildfires will likely increase in frequency over the next several decades because of climate warming (Ryan et al., 2008).
Regarding the Riano et al. (2007) study, although the authors found no global trends in burned area in the last 20 years, they found that burned area “did increase for the northern hemisphere in the mid-latitudes and subtropical areas of North America, Africa and southwest Asia” (including an earlier start for the fire season). This increase was compensated by decreases in tropical Southeast Asia and Central America. These conclusions are generally consistent with the TSD. Therefore, we find no evidence that contradicts the conclusions summarized in the TSD. This study is also discussed in our response (6-32) below.
Regarding the Kitzberger et al. (2007) study, we conclude this is generally consistent with the underlying scientific literature summarized in Section 10 of the TSD, which states that there are multiple influencing factors (e.g., forest management practices, natural climate variations, and changes in climate variables) on wildfire patterns.
Regarding the Zhang et al. (2008) study, we conclude it does not include any information about fire activity or drought in the western United States and therefore was not considered here.

For these reasons, we conclude that the TSD’s summary of the relationship between projected climate change and wildfire patterns is consistent with and accurately reflects the conclusions of the body of scientific literature.

Comment (6-32):
Two commenters (3283.1, 5846) indicate forest management practices in the past have contributed to the prevalence of recent wildfires, not climate change, and that risk would be reduced if land managers such as the USDA Forest Service were to implement better practices in the future.

Response (6-32):
Section 10(b) of the TSD summarizes the findings of the assessment literature with respect to the impact of climate change on wildfires. This discussion presents findings regarding observed changes to United States wildfires as well as information on projected trends. We note that the TSD includes multiple lines of evidence that climate change will affect wildfire risk and frequency; see the preceding response (6-31) for more information. We disagree with the commenters' assertion that anthropogenic climate change is not a significant factor that will influence the frequency and intensity of wildfires and drought in the western United States.

Consideration of forest management practices and concerns regarding the practices implemented by the USDA Forest Service are not germane to this action. See the Findings, Section III.C, "Adaptation and Mitigation," for our response to comments on the treatment of adaptation and mitigation in the Findings.

Comment (6-33):
At least one commenter (11459) indicates that current wildfires in California are receiving a lot of media attention, and at least one reporter has attributed its intensity to global warming. The commenter notes that anyone familiar with southern California wildfires are aware that the Santa Ana winds are one of the biggest factors in the ability of firefighters to control these wildfires. The commenter further states that in the 1930s, about 38 million acres were burned in the United States per year, and an average of 25 million acres per year were burned in the 1920s, and new fires were allowed to burn out because most of the forested areas had no buildings or people. In the 1990s, the average acreage burned was about 5 million per year. In the cool 1960s, the acreage burned also averaged about 5 million per year. According to the commenter, the big change has been the fuel buildup in these forested areas. The commenter cites Riano et al. (2007), which examined global satellite data for the period of July 1981 through December 2000. The commenter notes the study showed an increase in burned area in the western United States, but a decrease globally.

Response (6-33):
The commenter appears to dispute that wildfire activity, particularly in California, can be attributed to global warming. See Volume 3 for our responses to comments regarding the attribution of observed changes from climate including extreme events. We do not disagree with the commenter's statement that wildfire activity in southern California is correlated with climate systems such as the Santa Ana winds or El Niño and La Niña conditions. However, we note the commenter does not provide specific references for the information on acres burned in the United States, and we disagree that observed climate change has played no role in past wildfire activity. The scientific assessment literature as reflected in the TSD is clear that, with warming temperatures, both the frequency of large wildfires and the length of the fire season have increased substantially in recent decades in North America and will continue in the future. See our response (6-31) above for further response to this issue, including the Riano et al. (2007) study.

Comment (6-34):

Commenters (3347.1, 3447.3, 3747.1) assert that the information presented in the TSD regarding uncertainties in models used to represent disturbances such as wildfires do not support the Administrator's endangerment finding. The commenters state that because the TSD's discussion of disturbances such as wildfires relies on models with significant uncertainties, this information is not robust enough to support the Administrator's endangerment finding. One commenter additionally argued that EPA must provide estimates of nationwide net changes in wildfire frequency, scope, and intensity before the Agency could assess the risks to public health and welfare.

Similarly, a number of commenters (3347.3, 3427.1, 3440.1, 5846) argue that the TSD does not provide evidence to substantiate the statement from the Proposed Findings that climate change will cause more wildfires; thus, increasing wildfire frequency cannot be used as a justification for the endangerment finding. One commenter provides the following references as evidence that wildfire frequency is not increasing: Bergeron and Archambault (1993) and Bergeron et al. (2004). According to another commenter (3394.1), Higuera et al. (2009) find that past climate change has not been directly linked to increases in wildfires, that a variety of other factors are instead more closely related to increases in wildfire events, and that climate interactions with other factors can override any influence of climate change on wildfire events. Another commenter (3347.1) states that the TSD does not mention the benefit of forest fires for managed forest ecosystems.

Response (6-34):
The purpose of the TSD is to summarize the findings of the assessment literature, with appropriate uncertainty information. In this case, Section 10(b) summarizes the science on drought and wildfire risk. The TSD summary cites the IPCC (Field et al., 2007) "regarding a number of observed changes to United States wildfire size and frequency, often associated these changes with changes in average temperatures." These findings include:

> Since 1980, an average of about 22,000 km^2/year (8,500 mi^2/year) has burned in wildfires, almost twice the 1920-1980 average of about 13,000 km^2/year (5,020 mi^2/year).
> The forested area burned in the western United States from 1987-2003 is 6.7 times the area burned from 1970-1986.
> Human vulnerability to wildfires has increased, with a rising population in the wildland-urban interface.
> In the last three decades, the wildfire season in the western United States has increased by 78 days, and burn durations of fires greater than 1,000 hectares (ha) (2,470 acres) have increased from 7.5 to 37.1 days, in response to a spring/summer warming of 1.6°F (0.87°C).
> Earlier spring snowmelt has led to longer growing seasons and drought, especially at higher elevations, where the increase in wildfire activity has been greatest.
> In the southwestern United States, fire activity is correlated with ENSO positive phases (La Niña) and higher Palmer Drought Severity Indices. El Niño events tend to bring wetter conditions to the southwest, enhancing the production of fine fuels and, La Niña events tend to bring drier conditions. Major fire years tend to follow the switching from El Niño to La Niña conditions due to buildup of material during wet years followed by desiccation during a dry year, whereas small fires are strongly associated directly with previous year's drought. Other modes of atmospheric and oceanic variability are known to impact temperature and precipitation (Gutowski et al., 2008) and hence wildfire patterns and activity.
> Increased temperature in the future will likely extend fire seasons throughout the western United States, with more fires occurring earlier and later than is currently typical, and will increase the total area burned in some regions.

As noted by the commenter, the TSD also clearly acknowledges the state of the science with respect to wildfire modeling. It states, “Though fires and extreme events are not well represented in models, current climate modeling studies suggest that increased temperatures and longer growing seasons will elevate fire risk in connection with increased aridity.” The finding that fires and extreme events are not well represented in models does not preclude the consideration of how wildfires are changing *now* and are expected to continue changing due to climate change. We note the impacts and risks to forestry are assessed from more than just projections of extreme events related to future climate. Importantly, the TSD summarizes several studies that are based on observed changes, including the statement that “climate change has very likely increased the size and number of forest fires.”

We have reviewed the submitted studies and note that the IPCC (Easterling et al., 2007) cites the Bergeron et al. (2004) study; therefore, it has been reviewed and considered by the assessment literature on which the TSD primarily relies. Regarding the Bergeron and Archambault (1993) study, we note this study finds decreased fire frequency over a 300-year period after the end of the “Little Ice Age” (1688-1988). In addition, both of these studies focus on a specific fire regime in a boreal forest of Canada and thus, are not representative of the overall risks and impacts to U.S. forestry from climate change.

Regarding the Higuera et al. (2009) study, we note that the authors examine past relationships between fire dynamics and climate change over millennium time scales (the time scales over which human-induced climate change is generally most relevant span the near term over the next few decades and the longer term out to the end of the 21st century). Furthermore, we note the important contribution of the Higuera et al. study to our understanding of climate change effects on wildfires, but we do not conclude from the Higuera et al. study that our understanding that climate change increases the risk of wildfires, as stated in the assessment literature, should be immediately and fundamentally altered. Higuera et al. note that, “Although the response of fire regimes to climate change is complex and will vary regionally, there is general agreement that area burned across arctic and boreal regions will increase over the next century as climate change lengthens the fire season, decreases effective moisture, and increases ignition rates . These predictions are based primarily on short-term fire–climate relationships established in recent decades, but paleoecological studies also suggest that changes in relative moisture have influenced fire regimes throughout the Holocene.”

The TSD focuses on evaluating the impacts from changes in climate on the forestry sector; therefore, we do not evaluate the benefits of managed forest fires as related to managed forest ecosystems. See the Findings, Section III.C, “Adaptation and Mitigation,” for our response to comments on the treatment of adaptation and mitigation in the Findings. Finally, please see Section IV.B, of the Findings for a discussion of how the Administrator weighed the evidence related to the impacts of climate change on forests, and Sections II.A and IV.B of the Findings for our response to comments regarding the treatment of uncertainty in the Administrator’s endangerment determination.

Comment (6-35):
A commenter (3347.1) indicates that the TSD attributes to one of the IPCC chapters the implicit claim that climate change will increase the size and severity of wildfires in the United States. However, the commenter asserts that Easterling et al. (2007) make no such statement. The commenter states that EPA asserts climate change will cause more wildfires in the Summary section of the Proposed Findings, but that this claim is not supported anywhere else in the notice.

Response (6-35):
We have reviewed the TSD and Findings and disagree with the commenter’s characterization of the Proposed Findings and TSD with regard to citing the IPCC’s finding that climate change will increase the size and severity of wildfires in the United States. The summary section of the Proposed Findings stated,

"The effects of climate change observed to date and projected to occur in the future—including but not limited to the increased likelihood of more frequent and intense heat waves, more wildfires, degraded air quality, more heavy downpours and flooding, increased drought, greater sea level rise, more intense storms, harm to water resources, harm to agriculture, and harm to wildlife and ecosystems—are effects on public health and welfare within the meaning of the Clean Air Act." See Section IV.B.2 of the Final Findings for a discussion of forestry-related risks and impacts and how the Administrator weighed these issues in the endangerment finding to public welfare.

The TSD summarizes findings from both IPCC and CCSP with regard to the incidence of future wildfires. The CCSP indicates that "climate change has very likely increased the size and number of forest fires, insect outbreaks, and tree mortality in the interior west, the Southwest, and Alaska, and will continue to do so (Ryan et al., 2008)." In addition, the IPCC (Field et al., 2007) concludes, "Disturbances such as wildfire and insect outbreaks are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons (very high confidence)." Field et al. (2007) and Ryan et al. (2008) were primarily used to summarize this issue in the TSD since they focus on North America and the United States in particular. The commenter did not provide literature to support the conclusion that wildfires are not increasing. To be clear, the statement by Easterling et al. (2007) in Section 10(b) of the TSD on wildfires and drought risk indicates, "Some research identifies the possibility of a 10% increase in the seasonal severity of fire hazard over much of the United States under climate change." For these reasons, we conclude the TSD and the Findings accurately reflect and are consistent with the IPCC and other supporting scientific assessment literature.

Comment (6-36):

Some commenters (3136.1, 3596.2) dispute the conclusions of CCSP (and as cited in the TSD) from Westerling et al. (2006) regarding climate change and wildfires in the western United States. According to the commenters, Westerling et al. claim that increased wildfire frequency is caused by a trend toward earlier spring snowmelt. The commenters submit Figure 1b from Westerling et al. (2006) and claim it does not show a trend toward earlier spring snowmelt. Commenters also state that there is no correlation between global surface temperature and the Palmer Drought Severity Index in the western United States. In addition, they cite a study by Cook et al. (2004) that reconstructed western U.S. drought history back to 800 A.D. and found that compared to past megadroughts, the current drought does not stand out as an extreme event. The commenter concludes that the CCSP is therefore not a reliable source on the historical relationship between global temperature, drought, and western fires and should not be used as a source for the endangerment finding.

Response (6-36):

After careful review of the literature cited, we note that the commenter's interpretation of the Westerling et al. (2006) study from IPCC (Field et al., 2007) regarding the relationship between global temperature, drought, and wildfires in the western United States is not supported. Westerling et al. (2006) correlate wildfire with legitimate trends toward earlier spring snowmelt. Regarding drought, Westerling et al. do not correlate recent trends in wildfires with drought trends, contrary to the implication of the commenters.

Westerling et al. (2006) show that large wildfire activity increased suddenly and markedly in the mid-1980s, with higher large-wildfire frequency, longer wildfire durations, and longer wildfire seasons. They note the greatest increases occurred in mid-elevation, Northern Rockies forests, where land-use histories have relatively little effect on fire risks and are strongly associated with increased spring and summer temperatures and an earlier spring snowmelt.

We find that the commenter's conclusion that there is no trend toward earlier snowmelt is unsubstantiated. They indicate that Figure 1b in Westerling et al. (2006) shows no trend in snowmelt, but provide no analysis to support that statement. Furthermore, it is well-established that there have been trends toward earlier spring snowmelt in the West. In Section 4(j) of the TSD, we describe the CCSP (Lettenmaier et al., 2008) conclusion that finds where shifts to earlier snowmelt in the West. This conclusion is supported, in part, by the Stewart et al. (2005) study which finds: "Widespread and regionally coherent trends toward earlier onsets of springtime snowmelt and streamflow have taken place across most of western North America, affecting an area that is much larger than previously recognized."

Westerling et al. (2006) do not attempt to correlate drought with wildfires, but rather temperature. See Volume 2 for our responses to comments on observed drought trends, including a response to the Cook et al. (2004) study.

For these reasons we conclude that the TSD's summary of the science is accurate and reflects the current scientific literature. We disagree with the commenter's interpretation of the Westerling et al. study and conclude the relationship among spring snow melt timing, longer fires seasons, and drought, as described by the scientific assessment reports (IPCC and CCSP), is accurately reflected in the TSD.

Comment (6-37):

A commenter (3136.1) indicates that the TSD states "In the south-western U.S., fire activity is correlated ….with higher Palmer Drought Severity Indices." The commenter indicates that higher values of the Palmer Drought Severity Index mean wetter conditions, so both the TSD (Section 10b) and the IPCC (Field et al., 2007) finding it relies on are seemingly inconsistent with this by claiming that wetter conditions yield more fires, even though they are predicting drier conditions in the future. The commenter references a finding from McKenzie et al. (2004) that large fire years are associated with current-year drought but wetter-than-average conditions in the five previous years in the Southwest. The commenter states that, in contrast, the TSD predicts increasing frequency of drought in the Southwest caused by lower rainfall and higher temperatures, which would argue for fewer large fire years. The commenter concludes that the TSD's discussion of drought and fire is internally inconsistent and does not provide evidence that supports endangerment.

Response (6-37):

We have carefully reviewed the TSD and the underlying literature upon which these statements were derived. The statements in the TSD the commenter believes to be inconsistent are related to overall precipitation trends and fire activity in the southwestern United States. According to studies in the assessment literature, forest systems in the southwestern United States experience warm and wet conditions (higher Palmer Drought Severity Index) influenced by the El Niño ENSO events, followed by La Niña events that are associated with dry conditions (Westerling et al., 2003; McKenzie et al., 2004). This cycling results in buildup of fuel material during the wet years, followed by desiccation during a dry year as conditions follow the ENSO patterns. For this reason, major fire years tend to follow the transition from El Niño to La Niña conditions. Although the southwestern United States is expected to become drier in the future (Karl et al., 2009), this does not imply that these processes will not continue. We note that it is possible for a region to experience a long-term circulation pattern that produces drought, and to have short-term changes in this long-term pattern that result in short-term wet spells. Likewise, it is possible for a long-term wet circulation pattern to be interrupted by short-term weather spells that result in short-term drought. McKenzie et al. (2004) find that climate variability is a dominant factor affecting large wildfires in the western United States; however, they also note that it is unclear how these indices (e.g., Pacific Decadal Oscillation-PDO, ENSO) will respond to climate warming. In addition, the study finds that, "Increased temperature in the future will likely extend the fire seasons throughout the western U.S., with more fires occurring earlier and later than is currently typical, and will increase the total are burned in some regions." This is consistent with the IPCC (Field et al., 2007) and the summary in the TSD.

For these reasons, we disagree with the commenter that these statements from the TSD are internally inconsistent. See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination in general, and with regard to the forestry sector in particular.

Comment (6-38):
Commenters (3136.1 and 3596.2) state that the IPCC (Easterling et al., 2007) and EPA ignored the work of Nemani et al. (2003), which shows an enhancement of global vegetation in the last two decades. This study ascribes a 6% increase in global net primary productivity from 1982-1999 to the direct effect of warming temperatures and increased CO_2 concentrations. The commenters argue that the TSD speaks equivocally about the effects of climate change despite the availability of reliable data sensed from satellites.

Response (6-38):
We have reviewed Nemani et al. (2003) and note that this study is acknowledged and cited by the IPCC in the context of ecosystem properties, goods, and services in Fischlin et al. (2007). The Nemani et al. reference submitted by at least one commenter is consistent with the TSD statement that elevated CO_2 concentrations and moderate temperature increases over the near term can result in enhanced vegetative growth. The findings of Nemani et al. (2003) are broadly consistent with IPCC projections of an increase in carbon uptake or storage and an increase in net primary productivity (particularly in the tropics) in the early part of this century (Fischlin et al., 2007). However, we note that this reference considers the period from 1982 to 1999, whereas the TSD summarizes information on this issue over a longer time period and discusses future projections, thus exploring the important interplay of elevated CO_2 with projected temperature increases, and other relevant factors (e.g., changes in precipitation and tropospheric ozone). The summary of the scientific assessment literature in the TSD explains that there is regional variability in the responses of forest systems to climate change and thus, productivity gains in one area can occur simultaneously with productivity losses in other areas. Furthermore, there are a number of climate change effects that can act to offset forest productivity gains. Discussion of these and related issues of the varying impacts of climate change can be found in earlier responses to comments in this section.

We disagree with the commenter that the TSD is equivocal with respect to climate impacts. The discussion in Section 10 is clear that, while climate change may have positive impacts on the productivity of forest systems, changes in disturbance patterns are expected to have a substantial impact on overall gains or losses. As summarized in the TSD, the IPCC concludes with very high confidence that disturbances like wildfire and insect outbreaks are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons, and that continuing increases in disturbances are likely to adversely impact forestry by limiting carbon storage, facilitating invasive species, and disrupting ecosystem services.

Comment (6-39):
A commenter (3136.1) disagrees with the TSD statement that ecosystems in the northeast and southeast United States are projected to become carbon sources by the end of the 21st century. The commenter argues that this statement implies a very static use of forests, and that because they are largely managed ecosystems, efficient logging for wood products and housing will maintain forests as a carbon sink.

Similarly, a commenter (11166) indicates that without forest management, older trees will be retained on both private and public forest land, which produces less oxygen and then produces more carbon dioxide when they die or burn in forest fires. The commenter asks how the EPA will measure and regulate the CO_2 released by the death of older trees, and how much this regulation would cost the economy. The commenter indicates support for active forest management, forest protection, and forest fire control by professional foresters.

Response (6-39):
The statement referenced by the commenter, "By the end of the 21st century, ecosystems in the northeast and southeast United States are projected to become carbon sources, while the western United States remains a carbon sink," comes from the IPCC (Field et al., 2007), which cites a study by Bachelet et al. (2004). The Bachelet et al. (2004) study provides model projections of the carbon storage potential for various regions in the United States based on ecosystem type and other influencing climatic factors. The study primarily addresses the effects of changes in climate variables on the total ecosystem carbon pool and does not directly incorporate forest management practices into the analysis. Regarding the notion that effective management practices can prevent forests from becoming carbon sources, we did not separately assess different management scenarios over time. See the Findings, Section III.C, "Adaptation and Mitigation," for our response to comments on the treatment of adaptation and mitigation in the Findings.

The economic effects of potential future regulation and forest management activities are not within the scope of determining whether there is endangerment from elevated levels of GHG concentrations. See the Finding, Section III.C, "Adaptation and Mitigation," for our response to comments on the treatment of adaptation and mitigation in the Findings.

Comment (6-40):
A commenter (3283.1) references the TSD statement the Arctic/Sub-Arctic tree line has advanced 6 miles northward in the last 50 years, which is comparable to earlier Holocene changes. The commenter states that the Holocene period is representative of "natural" climate change conditions, and notes that birch forests existed on Greenland during the Medieval Warm Period, indicating that it was natural for tree ranges to extend further north than they do today. The commenter concludes that effects of changing forest composition are neutral, or even potentially beneficial, because they have happened before, and that any potential detrimental effects can be mitigated through adaptation and technology.

Response (6-40):
Section 10(c) of the TSD summarizes the findings of the assessment literature that climate change and associated changes in disturbance regimes will cause shifts in the distributions of tree species and alter forest species composition, which in turn can alter the frequencies, intensities, and impacts of disturbances such as fire, insect outbreaks, and disease. Regarding the effects of climate change on the Arctic tree line in particular, the TSD summarizes the conclusions of the Arctic Climate Impact Assessment (ACIA, 2004) that vegetation zones are projected to continue to migrate northward, with forests encroaching on tundra and tundra encroaching on polar deserts. We disagree with the commenter's notion that because northward migration of the treeline happened to some extent in the past, future shifts in the distributions of tree species will have only beneficial effects. The commenter provides no evidence to support this statement.

See the Finding, Section III.C, "Adaptation and Mitigation," for our response to comments on the treatment of adaptation and mitigation in the Findings.

Comment (6-41):

A commenter (3394.1) indicates that projections of invasive species impacts provided in the TSD should be reexamined in light of recent studies indicating that climate change will have considerably less of an impact in this regard (Sax and Gaines, 2008; Bradley et al., 2009).

Response (6-41):
See Volume 7, Section 7.3 of the Response to Comments document for our response to comments on the Sax and Gaines (2008) and Bradley et al. (2008) studies and invasive species impacts to ecosystems and wildlife.

Comment (6-42):
A commenter (3394.1) indicates that the TSD distorts the relevant science in this area by suggesting that ambient CO_2 levels could result in "noticeable die-off" due to root anoxia but fails to explain that this effect will not occur as a result of any projected CO_2 concentrations likely to occur. The commenter notes that, in fact, it has been observed only where CO_2 makes up 20% to 95% of soil gas, such as is found in areas exposed to volcanic activity. Thus, the commenter indicates this information is irrelevant and misleading.

Response (6-42):
We disagree with the commenter that the effects of elevated concentrations of CO_2 on vegetation are irrelevant and misleading, and upon review of the TSD language, we find that it places this statement in the appropriate context. The TSD provides a summary of the phototoxicity of CO_2 to vegetation from volcanic outgasing in the context of the direct effects of elevated GHG concentrations in Section 3. This provides evidence from the scientific literature regarding the biological response of plants from exposure to excessive CO_2 levels. Furthermore, the sentence in the TSD indicates that "no projections show CO_2 concentrations approaching these phytotoxic levels."

Comment (6-43):
A commenter (3394.1) states that EPA does not provide adequate detail on the potential competitive disadvantage of the United States compared to other regions in the international forest products market. Another commenter (3347.1) states that the TSD does not discuss how, with more potential forest inventory to harvest, the costs of wood and paper products to consumers are likely to decrease, as are the returns to owners of timberland.

Response (6-43):
In response to comments, EPA revised the TSD to remove the explicit discussion of the economic effects on the United States forest products industry in the context of broader global changes to timber markets, due to very limited supporting information from the underlying assessment reports. However, the introduction to Section 10 of the TSD does summarize one conclusion from the assessment literature regarding how global timber production may be affected by climate change: "Globally, the IPCC (Easterling et al., 2007) concludes that modeling studies predict increased global timber production but that regional production will exhibit large variability. However, Easterling et al. 2007 also notes CO_2 enrichment effects may be overestimated in models." In addition, Section 10(a) of the TSD states, "For the projected temperature increases over the next few decades, most studies support the conclusion that a modest warming of a few degrees Celsius will lead to greater tree growth in the United States. Simulations with yield models show that climate change can increase global timber production through location changes of forests and higher growth rates, especially when positive effects of elevated CO_2 concentration are taken into consideration (Easterling et al., 2007)." See Volume 11 of this Response to

Comments document for our response to comments on the implications of the Findings for economic and related concerns.

Comment (6-44):

Commenters (e.g., 2791, 10298) state their support for the Findings, noting the potential for increased stress from heat, drought, insects, and disease on plant and tree populations. Others (2599, 10081) from the western United States voice their support for the Findings and describe their experiences with hot summers and serious wildfires. Other commenters (e.g., 3421, 4748, 6894) state their support for the Findings and express concern about the effects of current and future extreme weather events on the forestry industry, including heat waves, droughts, floods, wildfires, and hurricanes. One commenter (5844) describes how projected climate impacts, particularly the increased risk of wildfire on forestry and forest biodiversity will affect him personally given his enjoyment of hiking, camping, and communing with nature in the forests of the Pacific Northwest.

A commenter (3501) states his support for the Findings, indicating that the western United States and Canada are already seeing widespread changes in the natural landscape due to climate change. Hotter temperatures are causing more frequent and persistent drought in the West, which contribute to forest fires and pine beetle infestations. A weather-related pine beetle infestation has decimated millions of acres of forest in the western United States Western US and Canada. At the current rate of destruction, 80% of the forests of British Columbia will have been destroyed within five years and the rest of the West will lose 50% of its forests by mid-century. The forest fire season in the West is now 78 days longer than 25 years ago and it is well recognized that our forest fires have become more frequent, more intense and more destructive.

Response (6-44):

We reviewed the comments provided and note they are generally consistent with the discussion of climate impacts on forestry in the TSD, although commenters do not provide specific references to support their claims. As summarized in the TSD and in our responses to previous comments in this volume, disturbances like wildfire and insect outbreaks are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons.

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