S.Reich
https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={B0FB92AF-C708-4D69-92FE-879C1DD3A192}&documentTitle=20159-113910-05
REBUTTALS TO Mendelsohn, Bezdek Rebuttals (Peabody tried to remove, but failed.)
p.5 "I have done fundamental and applied research in this area (climate change and forestry, with a specific focus on Minnesota) for more than two decades and have published widely in this area in leading scientific journals."
"I do not agree with Dr. Mendelsohn's view that Minnesota forests will benefit from near-term climate change. "
p.6 "Climate change will likely have both positive and negative effects on forests, with negative effects likely to outweigh positive effects in the near-term; and with the aggregate impact becoming increasingly negative looking further into the future. When we speak of "climate change" we need to recognize that this includes multiple changes simultaneously--these include impacts of CO2 concentrations and warmer temperatures; changes in soil water availability; and changes in insects, diseases, invasive species, and fire that result from climate change (and also influence forests). "
p.7 "However, other tree species, adapted to the historically cool climate of northern Minnesota and Canada, will fare poorly simply due to rising temperatures even if other factors are optimal."
"Evidence from our experiments shows that buckthorn benefits from climate change more than native northern Minnesota trees do (Reich et al 2015). Buckthorn has little (or negative) economic and ecological value and any extent to which its expansion is enhanced by climate change has negative repercussions for forest health and productivity." *(at least not kudzu)*
p.8 "that increased periods of limited water availability are already occurring due to climate change and will have a larger negative impact on forests than any positive effect of longer growing seasons and warmer summer temperatures."
p.10 "Milder winters and longer growing seasons which will occur with climate change are likely to be beneficial to insects and diseases, which in turn, will be detrimental to forest health in Minnesota"
p.12 "I note that Dr. Mendelsohn is an expert in forest policy and resource economics, and not in forest biology, tree physiology, or forest ecology, which are the sciences used to assess whether and how climate change will impact forests and their health and productivity. Consistent with this lack of expertise is that articles he cites to support his assertions about Minnesota forests are mostly global in nature (and thus have literally nothing tangible to say relevant to Minnesota), are largely computer models rather than empirical evidence, and are far from the most recent or relevant publication on the topic. ...
Thus, there is considerable relevant scientific literature, but none of it is referred to by Dr. Mendelsohn. "
p.13 (of Bezdek) 'Yes. I will respond to the assertion in Ex. 2 to his Rebuttal Testimony that he provided "examples of studies that demonstrate that increased carbon dioxide emissions and increased global temperature will result in increased crop production." He provides a list of 463 such "examples," although 36 of the citations are duplicative. ... **The list is not useful in this or any other situation. It would be deemed unsatisfactory to any peer-reviewed scientific publication, because the citations are in no particular order and are largely irrelevant to the assertion he was asked to support. '**
p.15 on corn (C4), not helped by CO2, whereas soybeans (C2) are, but the effect saturates; then ozone.
pp.18-51 CV

SURREBUTTAL TESTIMONY OF DR. PETER REICH,
F.B. Hubachek, Sr. Chair in Forest Ecology
University of Minnesota Regent's Professor

On Behalf of

Clean Energy Organizations

TABLE OF CONTENTS

I. INTRODUCTION.

Q. Please state your name and title.

A. My name is Peter B. Reich. I am a Regents Professor at the University of Minnesota, where I also hold the F.B. Hubachek Sr. Endowed Chair in Forest Resources.

Q. On whose behalf are you testifying?

A. I am testifying on behalf of the Clean Energy Organizations.

Q. What is the purpose of your testimony?

A. My testimony responds to assertions made in the Rebuttal Testimony of witnesses for Peabody Energy, Dr. Robert Mendelsohn and Dr. Roger Bezdek, concerning the likely impact of climate change on Minnesota's silvicultural and agricultural production.

Q. Please state your qualifications.

A. I am a professor at the University of Minnesota in the Forest Resources Department. My expertise is in the physiology and productivity of forests and grasslands, but I have also done research on agricultural crops. My research addresses impacts of climate change on a variety of aspects of plant physiology and ecosystem ecology. I have published more than 500 papers, including dozens in the leading journals such as Nature, Science, and the Proceedings of the National Academy of Sciences. During the past 15 years I have been among the 10 most cited researchers in the world in the field of environmental science and ecology. I was selected as a Regents Professor (the highest award possible) at the University of Minnesota in 2007. I also was named the BBVA Foundation Frontiers of

Knowledge Laureate in 2010 for Ecology and Conservation Biology. There is no Nobel Prize in ecology and the BBVA Award is considered one of a handful that most closely resembles that award. I only mention the above to make clear that I am a reputable, and in fact, well regarded scientist, internationally as well as in Minnesota. My CV is attached hereto as Schedule 1.

II. RESPONSE TO DR. ROBERT MENDELSOHN.

Q. Have you reviewed the direct and rebuttal testimony of Dr. Mendelsohn?

A. Yes.

Q. Are there particular assertions in Dr. Mendelsohn's testimony to which you will respond?

A. Yes.

Q. Please elaborate.

A. Dr. Mendelsohn offered in his Direct Testimony his belief that Minnesota is benefiting from a warming climate. He said:

> I believe that Minnesota is currently a net beneficiary of warming. Minnesota has no coastline along the Atlantic to suffer from sea level rise or future tropical cyclones. A warmer, wetter, CO_2-enriched world would be a clear gain for Minnesota agriculture. Ecological models suggest that Minnesota forests would become more productive and have more standing biomass as a result of near term climate change. A slightly warmer winter is likely to be beneficial as well and would offset possible damage from a slightly warmer summer. The state is not likely to be a net beneficiary if near term emissions are reduced.

Dr. Mendelsohn was asked to provide the basis for his assertion regarding Minnesota's forests. He attached his response to his Rebuttal Testimony, which states:

> Dr. Mendelsohn's views on ecosystem productivity under climate change were formed as part of his research on forests with Professor Sohngen. This research indicates that global forests will increase the supply of timber as a result of climate change.

He then cites a long list of articles.

My testimony is offered in response to the basis provided by Dr. Mendelsohn for his belief that Minnesota will benefit from a warming climate.

Q. Are you familiar with the peer reviewed literature on climate change and forestry, including the likely effect of climate change on Minnesota forests?

A. Yes. I have done fundamental and applied research in this area (climate change and forestry, with a specific focus on Minnesota) for more than two decades and have published widely in this area in leading scientific journals. To do so requires being familiar with all other relevant literature. Our research includes studies of plant growth, survival and physiology in response to historical climate change, to existing climate gradients, and to experimental climate manipulations in the field. Thus I am likely one of a handful of scientists most knowledgeable about these issues.

Q. Do you agree with Dr. Mendelsohn's assertion that Minnesota forests will benefit from climate change?

A. No, I do not agree with Dr. Mendelsohn's view that Minnesota forests will benefit from near-term climate change.

https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={B57000B8-28E6-430B-A63B-BF645D6C5261}&documentTitle=20159-114135-01
MLIG and Peabody tried to exclude Reich's entire testimony.
p.2 the ALJ struck the single sentence shown.

Q. Please explain why you disagree with Dr. Mendelsohn's assertions regarding Minnesota forests.

A. Climate change will likely have both positive and negative effects on forests, with negative effects likely to outweigh positive effects in the near-term; and with the aggregate impact becoming increasingly negative looking further into the future. When we speak of "climate change" we need to recognize that this includes multiple changes simultaneously--these include impacts of CO_2 concentrations and warmer temperatures; changes in soil water availability; and changes in insects, diseases, invasive species, and fire that result from climate change (and also influence forests). In the following paragraphs I explain how these will likely influence Minnesota forests. Because the forests differ biologically and climatically I will focus on northern Minnesota, where the vast majority of Minnesota forests are located, but will also comment on southeastern Minnesota forests briefly and occasionally. ~~Also, given that wildlife require specific habitats to grow in, changes in the tree components of forests will certainly influence all of Minnesota's wildlife species.~~

A. CO_2 concentrations and warmer temperatures.

Rising CO_2 levels, warming temperatures, and a longer growing season will improve growth of some tree species, *if* they have sufficient water and are free from insect pests, diseases, and fires (see below). However, other tree species, adapted to the historically cool climate of northern Minnesota and Canada, will fare poorly simply due to rising temperatures even if other factors are optimal. They simply are designed, like a moose, to

functional well under cool temperatures and suffer from poor performance or even heat stress, when temperatures are higher. Spruce and fir, two dominant species in northern Minnesota (they make up 30 percent of all trees in northeastern MN; Friedman & Reich 2005) grow much more poorly (by as much as 30-40 percent more slowly) with even slight warming (Fisichelli et al. 2012, Reich et al. 2015). Of the other key northern species, two (white pine and jack pine) also decrease growth with warmer temperatures, while two others (aspen and paper birch), have neutral responses (Reich et al. 2015). Other species can grow faster with warmer temperatures, particularly maples and oak (Reich et al 2015), but these species are historically more southern in their range (growing from southern Minnesota to Arkansas) and currently rare in much of northern Minnesota. Given that trees migrate very slowly on their own, and that due to high costs there is very little tree planting of new forests, it may take a generation for even the best performing trees to replace poor performers in the existing northern forests (i.e. those with significant components of spruce, fir, or pine), that may decline in the intervening time period. Additionally, invasive non-native shrubs, such as buckthorn, are likely to become more aggressive and abundant in northern Minnesota with climate change. Evidence from our experiments shows that buckthorn benefits from climate change more than native northern Minnesota trees do (Reich et al 2015). Buckthorn has little (or negative) economic and ecological value and any extent to which its expansion is enhanced by climate change has negative repercussions for forest health and productivity. Thus, even ignoring potential stress from drought, insects, disease, and fire, near-term

climate change is likely to be negative for northern Minnesota forests and slightly negative to slightly positive for southeastern Minnesota forests.

B. Changes in soil water availability.

The impacts of CO_2 concentrations and warmer temperatures noted above will not occur in isolation; rather they influence, and will be influenced by, other associated changes. Recent research from southern Canadian forests (similar to northern Minnesota forests) and from our own research in Minnesota suggests that increased periods of limited water availability are already occurring due to climate change and will have a larger negative impact on forests than any positive effect of longer growing seasons and warmer summer temperatures. This is due to two reasons: first, with climate change our rain falls in fewer, heavier events, during which a larger fraction of the rain runs off into streams and rivers, and less goes into recharging the soils; and second, in the future, warmer plants and soils will evaporate more water, meaning that the forest will need higher rainfall than today to even 'stay even' in terms of sufficient water supply. Both of these processes are well documented scientifically. Here are additional details about the first of these processes. Predictions of future rainfall amounts are highly uncertain, but much more certain is that whatever rainfall we get will come in fewer, more intense (heavy rainfall) events. When such events happen a considerable fraction of the rain runs off, meaning less enters the soil. Thus, even if we get the same amount of rain, less of it goes into the soil, and the dry time periods between rain events will be longer than in the past. This makes the forest effectively drier than it was in the past. Regarding the second process (evaporation from

forests), simple biophysics means that with similar total amount of moisture in the atmosphere but with warmer air, soils and trees, the evaporative gradient is greater and the evaporation rates will increase. This means that even if the same total amount of water enters the soil in summer, the forest becomes effectively droughtier because a greater amount of water is lost, and more quickly. The combination of greater evaporation of water from forests, less soil recharge from whatever rain does fall, and longer periods without rain between rainfall events, collectively means that growth of Minnesota forests will be increasingly slowed down by lack of sufficient soil water. The fact that most forests in northern Minnesota grow on thin, rocky soils or sandy, pebbly soils with poor water-holding capacity, exacerbates likely problems with soil water shortages.

Evidence supporting the above assertions is abundant from comprehensive long-term Canadian records, which show that lack of water has already resulted in both slower growth of southern Canadian forests and greater mortality of most important tree species (including aspen, pine, and spruce), during the recent few decades (Ma et al. 2012, Peng et al. 2011). Canadian forests have performed most poorly to the west of Minnesota (where it is drier) and more neutrally to the east (where it is wetter than Minnesota), and most poorly nearer the border with the U.S. than further north; hence the average poor performance of Canadian forests during the past few decades is likely a reasonable predictor of the future performance of northern Minnesota forests.

C. Changes in insects, diseases and fire.

Insect pests and tree diseases in cold climates are held somewhat in check by the coldest temperatures of mid-winter (which can be lethal) and by the short growing season (that limits their population growth). Milder winters and longer growing seasons which will occur with climate change are likely to be beneficial to insects and diseases, which in turn, will be detrimental to forest health in Minnesota (Handler et al. 2014). Predicting the severity of these impacts is difficult, but we can be confident they will range from mildly detrimental to catastrophic, and are extremely unlikely to be beneficial. The greater incidence of soil water shortages (explained above) and damages from insects and diseases would all lead to more dead branches and trees (which equals more fuel for wildfires). The greater incidence of high temperatures and dry conditions will lead to more opportunities for wildfire, and greater fuel loads will make such fires more destructive. An increase in the number of windstorms is also uncertain, but plausible. Such windstorms, like the July 4, 1999 blowdown, would be both directly damaging to forests and provide additional dry fuel for fires. Collectively, climate change will increase problems with insects, diseases, and forest fires. Although it is impossible to predict precisely how bad these problems will be, they are likely to be large enough to offset any gains from warmer temperatures and rising CO_2, in terms of forest health and productivity.

D. Likely aggregate influence of climate change on Minnesota forests.

In years when rainfall is similar to or less than historical averages, and/or insects, diseases, or invasive plants are at higher levels, trees will perform more poorly than in the 20th century, despite higher CO_2 levels and temperatures. Any increase in the area and severity of forest fires will further adversely affect forest biomass and productivity. In years when rainfall is above average, and insects, disease and invasive plants are at low levels, rising CO_2 and warmer temperatures in the near-term will likely make Minnesota forests grow faster in the southeastern part of the state (where dominant species are adapted to a wide and warmer range of temperatures than in northern Minnesota). Under such conditions, northern Minnesota forests likely will show a range of responses, from positive to neutral to negative depending on species make-up, soil depth, and other factors (Handler et al. 2014). Years with above average rainfall and without insect, disease, and invasive plant species problems are likely to become scarcer and scarcer as the climate warms. Thus, very near-term impacts of climate change (next 10 years or so) are likely to be slightly to moderately negative in northern Minnesota and near neutral (ranging from mildly positive to mildly negative) in southeastern Minnesota. Near-term impacts (looking out 20 to 30 years) are likely to be negative to strongly negative in northern Minnesota and neutral to negative in southeastern Minnesota; as the negative effects of water limitations, heat stress, insects, diseases, invasive plants, and wildfire are all likely to grow worse as climate change continues.

In sum, based on my own research as well as the peer reviewed scientific literature, I conclude that Dr. Mendelsohn's belief that Minnesota forests will benefit from near-term warming is incorrect.

Q. Do you have any other response to Dr. Mendelsohn's testimony?

A. I note that Dr. Mendelsohn is an expert in forest policy and resource economics, and not in forest biology, tree physiology, or forest ecology, which are the sciences used to assess whether and how climate change will impact forests and their health and productivity. Consistent with this lack of expertise is that articles he cites to support his assertions about Minnesota forests are mostly global in nature (and thus have literally nothing tangible to say relevant to Minnesota), are largely computer models rather than empirical evidence, and are far from the most recent or relevant publication on the topic. For example, he cites nothing published within the past six years and almost 20 references that are one to three decades old. There was nothing wrong with the science done at that time, but this is a field of great activity, and both our knowledge base, and the very forests we are attempting to understand, are in flux. Thus, there is considerable relevant scientific literature, but none of it is referred to by Dr. Mendelsohn. In sum, the references he claims as support say nothing relevant about Minnesota forests yesterday, today, or in the decades to come.

III. RESPONSE TO DR. ROGER BEZDEK.

Q. Are there specific points in the testimony of Dr. Bezdek to which you will respond?

A. Yes. I will respond to the assertion in Ex. 2 to his Rebuttal Testimony that he provided "examples of studies that demonstrate that increased carbon dioxide emissions and increased global temperature will result in increased crop production." He provides a list of 463 such "examples," although 36 of the citations are duplicative.

Q. Have you reviewed this list?

A. Yes.

Q. What is your overall impression of this list?

A. The list is not useful in this or any other situation. It would be deemed unsatisfactory to any peer-reviewed scientific publication, because the citations are in no particular order and are largely irrelevant to the assertion he was asked to support. For example, on page 36 of this exhibit, he begins citing studies dealing with ocean acidification due to increased levels of CO_2. This continues for approximately 13 pages. Ocean acidification studies are not relevant to whether increased carbon dioxide emissions and increased global temperature will result in increased crop production. Also, many of these sources are not from peer-reviewed scientific literature, so they are of little value.

Q. Three of the sources he includes list you as an author or co-author:

Reich, P.B. 2009. Elevated CO_2 reduces losses of plant diversity caused by nitrogen deposition. *Science* 326: 1399-1402.

Lau, J.A., Shaw, R.G., Reich, P.B. and Tiffin, P. 2010. Species interactions in a changing environment: elevated CO_2 alters the ecological and potential evolutionary consequences of competition. *Evolutionary Ecology Research* 12: 435-455.

Peters, E.B., Wythers, K.R., Zhang, S., Bradford, J.B. and Reich, P.B. 2013. Potential climate change impacts on temperate forest ecosystem processes. *Canadian Journal of Forest Research* 43: 939-950.

Were you involved with these articles?

A. Yes.

Q. Do these articles conclude that increased carbon dioxide emissions and increased global temperature will result in increased agricultural crop production?

A. None of these articles is relevant to agricultural crop production. The first is about how CO_2 and N deposition influence the diversity of perennial prairies. The second is about a test organism, *Arabidopsis*, that is akin to the fruit fly in that it is widely used to assess fundamental biological processes under controlled laboratory conditions and was the first plant to have its entire genome sequenced. *Arabidopsis* is not a crop, nor does it resemble one in any fashion. The third article reports the results of a computer model about forest growth. Given that this was a model exploration (i.e., no measured data) and involved forests, not crops, it also seems irrelevant to the topic at hand. In short, as none of these three papers are relevant to the topic, none of them conclude anything (one way or the other) about how rising CO_2 and warmer temperatures will influence crop production.

Q. Do you have an opinion on whether increased concentrations of CO_2 and higher global temperatures will benefit agricultural crop production?

A. I do not agree with Dr. Bezdek (or Dr. Mendelsohn) that increased CO_2 and temperature will result in a net benefit to agricultural crop production in Minnesota. As set out in the rebuttal testimony of Dr. Stephen Polasky (p. 53-54), many of the same issues affecting forest productivity affect agricultural crop yields, including water availability, pests and pathogens. Here are a few additional points, which I have gained from 30 years of research studying impacts of CO_2, temperature, water, ozone and other factors on physiology, growth and yield of trees, grasses, and crops. First, one of the main crops in Minnesota, corn, has a photosynthetic physiology (called C4 photosynthesis) that evolved to greatly increase the concentration of CO_2 at the site of photosynthesis inside of the leaf. It has long been proven that species with this C4 physiology have minimal increases in productivity due to rising CO_2 (Ainsworth and Long 2005). Second, the increase from a pre-industrial CO_2 concentration of approximately 280 ppm to today's roughly 400 ppm has likely boosted growth and to a lesser extent, yield, of crops like soybean that do not have the C4 pathway, because CO_2 levels at the site of photosynthesis tended to be in limiting supply at 280 ppm, and less so at 400 ppm. However, as the response to rising CO_2 is what scientists call a "saturating curve" (meaning that each incremental increase brings less additional gain), increases of CO_2 above 400 ppm in the future will have less and less positive effect, the higher the CO_2 levels rise. Third, the same processes that increase the CO_2 concentrations in our atmosphere (i.e., burning of fossil fuels) also contribute to the formation of increased ozone concentrations (because fossil fuel burning

also emits precursors to ozone, such as NOx and hydrocarbons)(IPCC 2013), which occur nationally in agricultural regions. Ozone damages the lungs of people and other animals and also damages the membranes of any plant cells it encounters. The increased concentrations of ozone are not sufficient to cause visible leaf damage, but are sufficient to reduce the photosynthesis, growth and yield of crops, likely offsetting much or all of benefit that might result from CO_2 or warming. Fourth, crop breeding has advanced considerably, and MN crops are bred already to match current temperatures and daylengths; it is not at all clear that warmer temperatures (assuming well-watered soils) will provide any further gain. Taken together, the evidence indicates that crop response to rising CO_2 and climate change, including associated effects on water availability, ozone pollution, pests, and pathogens, is complex. Any statement that simply claims MN agriculture will benefit because plants need CO_2 and warm weather is unrealistically simple. Agriculture is a complex applied ecological science. There is a chance that some crops in some years might do better because of higher CO_2 and temperatures. However those gains are likely to be modest to very modest. In contrast, disruptions due to increased drought, pests, heat stress, and pathogens are potentially enormous. I don't believe that we, the scientific community, has sufficient scientific understanding to accurately predict whether, and by how much, MN crop production will increase or decrease with climate change. My opinion is that the risks have much more downside potential than the benefits have upside potential. However, there is certainly is no evidence to support the notion that MN agriculture will generally benefit from rising CO_2 and associated climate change in the next several decades.

Q. Have you provided full citations for the articles cited throughout your testimony?

A. Yes, a reference list is attached following this testimony.

IV. CONCLUSION

Q. Does this conclude your testimony?

A. Yes.

V. REFERENCES

Ainsworth, E. A. & Long, S. P.What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2. New Phytol. 165, 351_372 (2005).

Friedman, SK, PB Reich. 2005. Regional Legacies of Logging: Departure from presettlement forest conditions in northern Minnesota. Ecological Applications 15:726-744.

Fisichelli, N, LE Frelich, PB Reich. 2012. Sapling growth responses to warmer temperatures 'cooled' by browse pressure. Global Change Biology 18:3455–3463, doi: 10.1111/j.1365-2486.2012.02785.x

Handler, S, M Duveneck, LIverson, EPeters, R Scheller, K Wythers, L Brandt, P Butler, M Janowiak, PDShannon, C Swanston, K Barrett, R Kolka, C McQuiston, B Palik, P Reich, C Turner, M White, C Adams, A D'Amato, S Hagell, P Johnson, R Johnson, M Larson, S Matthews, R Montgomery, S Olson, M Peters, A Prasad, J Rajala, J Daley, M Davenport, M Emery, D Fehringer, C Hoving, G Johnson, L Johnson, D Neitzel, A Rissman, C Rittenhouse, R Ziel. 2014. Minnesota forest ecosystem vulnerability assessment and synthesis: a report from the Northwoods Climate Change Response Framework. Gen. Tech. Rep. NRS-133. Newtown Square, PA; U.S. Department of Agriculture, Forest Service, Northern Research Station. 228 p.

IPCC (2013) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, NY USA.

Ma, Z. et al. Regional drought-induced reduction in the biomass carbon sink of Canada's boreal forests. Proc. Natl Acad. Sci. USA 109, 2423_2427 (2012).

Peng, C. et al. A drought-induced pervasive increase in tree mortality across Canada's boreal forests. Nature Clim. Change 1, 467_471 (2011).

Reich, PB, KM Sendall, K Rice, RL Rich, A Stefanski, SE Hobbie, RA Montgomery. 2015. Geographic range predicts photosynthetic and growth response to warming in co-occurring tree species. Nature Climate Change 5:148-152.

CURRICULUM VITAE OF PETER B. REICH

September 2015

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Marine on St. Croix, MN 55047
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EDUCATION

Ph.D. (1983) Department of Natural Resources
Cornell University, Ithaca, New York
Major in environmental biology and plant ecology

M.S. (1977) School of Forestry, Fisheries and Wildlife
University of Missouri, Columbia, Missouri
Major in forest ecology

B.A. (1974) Goddard College, Plainfield, Vermont
Majors in creative writing and physics

PROFESSIONAL EXPERIENCE (post-Ph.D.)

Professor and F.B. Hubachek, Sr. Chair, University of Minnesota (1991- present)
Distinguished McKnight University Professor, University of Minnesota (2003- present)
Regents Professor, University of Minnesota (2007- present)
Resident Fellow, University of Minnesota Institute on the Environment (2009-present)
Foundation Director (2011-13), Chief Scientist (2013- present), Hawkesbury Institute for the Environment, University of Western Sydney, Richmond, NSW, Australia (joint affiliation with U. of Minnesota)
Member, Graduate Faculties: Ecology, Evolution and Behavior; Forest Ecology and Management; Plant Biological Sciences; and Conservation Biology Programs; University of Minnesota (1991- present)
Visiting Research Fellow, Laboratorio Ecotono, Universidad Nacional de Comahue, Bariloche, Argentina, 2005
Distinguished Visiting Fellow, Dept Biological Sciences, Macquarie University, Sydney, Australia, (1998-99)
Associate Professor (1989-91), Assistant Professor (1985-89)
Department of Forestry, University of Wisconsin, Madison, WI
Postdoctoral Associate (1983-85), Boyce Thompson Institute; Cornell University, Ithaca, NY

UNIVERSITY SERVICE (selected, since 2004)

Cornerstone Team (Co-Chair): Accelerate Transfer of Knowledge for the Public Good (one of four bases of Five-Year Strategic Plan, Office of the Vice-President for Research), University of Minnesota, 2014-
Distinguished McKnight Professorship Selection Committee (Member), University of Minnesota, 2008-2010
Biosphere-Atmosphere Science Search Committee (Member), Department of Soil, Water, and Climate and Department of Forest Resources, 2007
Silviculture Search Committee (Member), Department of Forest Resources, 2006-07
Dean Search Committee (Member), College of Food, Agriculture, and Natural Resources Sciences, 2006
University of Minnesota Committee to Develop a Blueprint for the Institute on the Environment (Member), 2006
Forest Ecology Search Committee (Chair), Department of Forest Resources, 2004
Vice-President for Research Search Committee (Member), University of Minnesota, 2004
Cedar Creek Natural History Area Executive Committee (Member), 2001- 2008

HONORS, PROFESSIONAL RECOGNITION, SYNERGISTIC ACTIVITIES, AND SERVICE (selected)

American Academy of Arts and Sciences, Member (elected in 2011)
BBVA Prize Laureate (BBVA Foundation Frontiers of Knowledge Award in Ecology and Conservation Biology; Madrid, June 2010)

Citation Indices: Google Scholar (February, 2015), total = 49,481 from 451 articles, 25,694,107 since 2010; h-index = 110; Web of Science Citation Index (December 2014): total = 36,567 from 453 articles, 4,180 in 2014; h-index = 100. According to Thompson Reuters Web of Science, among Most Highly Cited 20 Ecologists and Environmental Scientists in the World (out of ≈ 500,000), every 10-year period 1991-2001 to 2004-2014 (current position, 8th)

Invited speaker and keynote addresses, >175 national/international symposium, research conferences, government, agency, and university seminars; e.g., selected, Australian National Univ. (2011), BIOGEOMON 2014 International Conference, Keynote Speaker, Univ of Bayreuth, Germany (2014), Carleton College (2014), Centre d'étude de la forêt, Annual Conference, Keynote Address, Port Orford, Quebec, March (2010); Chicago Botanic Garden (2012); Cornell Univ. (1997, 2006); DOE Terrestrial Ecosystem Science Annual Meeting (2014); Duke Univ. (1999, 2003, 2008); Fundación BBVA, Biodiversity and Global Change Lecture Series, Madrid and Barcelona, Spain (2007); Gordon Research Conference, Metabolic Basis of Ecology (2004, 2006); Harvard Univ., Biodiversity, Ecology, and Global Change Lecture Series (2007); Harvard Univ. 6th Symposium on Plant Biology (2010); Hokkaido Univ. (1993); Indiana Univ. (2009); Kyoto Univ. (1993); Lakehead Univ., Ontario, Canada (2010); Lanzhou Univ., (2014); Macquarie Univ., Sydney, Australia (1999, 2007, 2013); McGill Univ. (1999, 2005, 2007); Nanjing Univ. (2014); Nanjing Univ. of Information, Science and Technology (2014); Northern Arizona U. (2010); 24th New Phytologist Symposium - Plant respiration and Climate Change, Oxford Univ. (2010); Peking Univ. (2014); Pennsylvania State Univ., Invited Speaker, 7th Plant Biology Symposium (2009); Princeton Univ. (The John Bonner Lecture)(2006); Stanford Univ. (Inaugural Global Change Series, 2004); SUNY-ESF (2012); SUNY Stony Brook (2006); Texas A& M Univ. (2004, 2008); Vrije Universiteit, Amsterdam; Universidad Comahue (Bariloche, Argentina)(2005); Universitat Autònoma de Barcelona (2007); Univ. of Colorado (2001); Univ. of Connecticut (2010), Univ. of Georgia (2008); Univ. of Illinois (2001); Univ. of Massachusetts Symposium on Plant Biology (2004); Univ. of Melbourne (2013), Univ. of Missouri (2008); Univ. of Nebraska (2012); U. of Nevada (2009); Univ. of Quebec at Montreal (2011); Univ. of Washington (1988); Univ. of Wisconsin-Madison (2013); Univ. of Wisconsin-Milwaukee (2013); Washington Univ. (2003); West Virginia U (2012).

Co-founder, Writer, Editor, MinuteEarth YouTube Channel https://www.youtube.com/user/minuteearth dedicated to advancing scientific understanding and interest in earth and environmental science, global change science, and ecology (>50 videos released; >1,000,000 subscribers and > 50 million views since March 2013).

Editorial Board, Topics in Statistical Ecology, Springer (2011-)

Co-chair, Physiological Ecology Section, Faculty of 1000 (2010-)

Scientific Advisory Board, FunDivEUROPE (FUNctional significance of forest bioDIVersity in EUROPE) Project, 2010 - present

Climate Science Rapid Response Team (charter member, 2010-), scientist network providing rapid, high-quality information to media and government

Minnesota Forest Resources Council, Research Advisory Committee (2008- present)

Commissioner, Mahtomedi City Environmental Commission (2007-2010)

Nature Research Highlight. Our experiment *(B4Warmed: Boreal Forest Warming at an Ecotone in Danger*) featured in *Nature*, 30 July 2009 "Forest growth studies begin to turn up the heat", Vol. 460, p. 559.

Commencement Speaker, Univ. of Minnesota Graduate School commencement, "Dancing on Thin Ice", May 9, 2008

Nature Research Highlight. Our paper *(Holdsworth et al. 2007, Conserv. Biol.*) featured in *Nature*, 23 August 2007 "Worm Wood", Vol. 448, p. 843.

Co-initiator of the "Minnesota 2050: Pathways to a Sustainable Future" Project, partnership with >100 citizens from multiple stake-holder groups, working towards a public policy and education-relevant vision of an environmentally and economically sustainable regional future.

Nature Research Highlight. Our papers *(Wright, Reich, Westoby & GLOPNET 2004, Nature; Shipley et al. 2006, Ecology*, and two others) featured in *Nature*, 30 November 2006 "The costs of leafing", Vol. 444, p. 539-541.

Founding Member, Mahtomedi Area Green Initiative (2007), Mahtomedi, MN

U.S. GAO/National Academy of Sciences Workshop on Climate Change Effects on Federal Lands, November 2006, Washington, D.C.

The ARC-NZ Research Network for Vegetation Function, 2005-2010, M. Westoby, I. Wright, co-conveners (Reich is a Core Participant)

Nature Research Highlight. Our paper (*Reich et al. 2006, Nature*) featured in *Nature* News & Views, by L. Hedin, 26 January 2006, "Plants on a different scale", Vol. 439, pp. 399-400.

Department of Energy, National Institute on Climate Change Research, Midwestern Regional Panel, 2006-07
Institute for Scientific Information (ISI) Science Citation Index, One of Top 3 Papers in "Environment and Ecology" in the World, 2004-2006 (Wright, Reich, Westoby and Glopnet 2004, Nature).
Australian Journal of Botany, Editorial Board 2006-
Oecologia, Editorial Board, 2006 – 2013
Science, Editor's Choice and *PNAS* Commentary. Our paper *Reich & Oleksyn 2004, PNAS* featured in *Science,* 16 July 2004 "Limits from Leaf Litter", Vol. 305, p. 311, and in *PNAS* Commentary by L. Hedin, "Global organization of terrestrial plant-nutrient interactions", 27 July 2004,101, 10849-10850.
Science, Editor's Choice. Our paper *Reich et al 2004, Ecol Monogr* featured in *Science,* 26 March 2004 *"The demographics of leaves" Vol. 303, p.1949.*
Australian Journal of Botany, Editorial Advisory Committee, 2003- 2006
Faculty of 1000 Biology, 2006-
Tree Physiology, Editorial Review Board, 2004-2007
Eurasian Journal of Forest Research, Editorial Advisory Board, 2004 -
National Science Foundation (USA), Biocomplexity and the Environment Program, Coupled Biogeochemical Cycles Panel Member, 2004
Distinguished Ecologist Lecture, Michigan Technological Univ., 2003
Chair of External Review Committee, for the Intercollegiate Ecology Graduate Program at Penn State Univ., University Park, PA, 2003
Lecturer, Intensive International Graduate Student Course, Functional Diversity in Ecosystems, University of Chile and University of Concepción; Concepción Chile, January 2001
Organizer, North American Forest Ecology Workshop, 2001, Duluth, MN
Environment 2000 Lecture, University of Illinois, Champaign-Urbana, 2000
Barnett Endowed Lecture, University of Michigan Biological Station, 1999
Distinguished Lectureship, University of Western Australia, Perth, Australia, 1999
Distinguished Visiting Fellow, Macquarie University, Sydney, Australia, 1998-99
Subject Editor, *Ecology* and *Ecological Monographs*, 1995-98
National Science Foundation (USA), Ecological and Evolutionary Physiology Panel Member, 1994-97
National Science Foundation (USA), LTER Program Coordinating Committee 1994-96
Associate Editor, *Canadian Journal of Forest Research* (Forestry Canada), 1992- 98
Member, Editorial Board, *Trees* (Springer-Verlag), 1991-1996
National Research Council Panel, NAS; Future of Atmospheric Chemistry Research, August 1995
Presidential Young Investigator Award, National Science Foundation (USA), 1988-1993
Japan Science Board, Visiting Professor Research Exchange Fellowship, 1993
National Academy of Science Scientific Exchange Award, 1991
Member, Editorial Review Board *Tree Physiology* (Heron Publishing), 1987-88, 1993-95
USDA National Research Initiative Grants Program, Plant Response to the Environment Panel member, Washington, D.C., 1991
USDA Competitive Grants Program, Forest Biology Panel member, Washington, D.C., July 1990
Center for Forest Environment Studies, U.S. Forest Service, Macon, GA, member of Technical Steering Committee, 1990-1994
Pound Award for Excellence in Research, University of Wisconsin, 1989
U.S. Forest Service, Forest Response Program - Served on Review Panel for Southern Commercial Forest Response Cooperative Research Program, Raleigh, NC, March 1986
Andrew D. White Fellowship, Cornell University, Ithaca, NY, 1978-1981

UNIVERSITY COURSES TAUGHT

Forest Ecology
Plant Physiological Ecology
Dynamics of Global Change: Plant Ecology
Plant Responses to Air Pollution
Climate Change Seminar
Scaling Seminar
Landscape Ecology
Tree Physiology
Tropical Forest Ecology
Plant Nutrition, Species Ecology and Nutrient Cycling
Patch Dynamics
Ecophysiology of Managed & Natural Ecosystems
Science & Policy of Global Environmental Change

MENTORING

Formal advisor of 35 students who have received MS or PhD degrees and mentor to an additional ≈30 scientists (grad students/postdocs) from 20 countries (*co-advised).

PhD: *Alex Roth (2015), Alexandra Lodge (2015), *Kerrie Sendall (2012), *Nick Fisichelli (2012), *Christel Kern (2011), *Kris Johnson (2010), *Nick Danz (2008), Mark Norris (2007), Ann Pierce (2006), *Andy Holdsworth (2006), Kathleen Knight (2006), *Roy Rich (2005), *Cindy Hale (2003), Kim Chapman (2001), *Martin Dovciak (2001), Steve Friedman (2001), Tali Lee (2001), Mike Tobin (2001), *Meredith Cornett (2000), Jose-Luis Machado (1999), Dave Peterson (1998), Mark Tjoelker (1997), Dirk Vanderklein (1995), Mike Walters (1994), John Volin (1993), Eric Kruger (1992) David Ellsworth (1991)

MS: *Chris Pinahs (2012), *Brian Pelc (2008), Autumn Sabo (2003), Daren Carlson (2001), *Scott Weyenberg (2001), *Meredith Cornett (1996), Janet Eckhoff (1994), Leonora Ko (1989)

Postdoctoral Research Associates: *Adair C, *Aspinwall M, Butler E, *Dijkstra F, Boyden S, Dickie I, *Drake J, Eisenhauer N, *Flores H, Frelich L, Heskel, M, *Lebrija E, Lee T, Milla R, Montgomery R, *Mueller K, Oleksyn J, Peters E, *Pfautsch S, Rich R, Schnitzer S, *Schrodt F, Strengbom J, Tjoelker M, *West J, Whitfeld T

GRANTS RECEIVED (since 1986)

Department of Energy, Earth System Modeling Program, "Global land model development: time to shift from a plant functional type to a plant functional trait approach", 2014-2017 [P Reich PI, A Banerjee co-PI], $1,347,500

National Science Foundation (USA), Dimensions of Biodiversity Program, "Linking remotely sensed optical diversity to genetic, phylogenetic and functional diversity to predict ecosystem processes", 2013-2018 [J. Cavender-Bares, S Hobbie, R Montgomery, P Reich, U Minnesota; collaborators at four other institutions), $2,000,000.

National Science Foundation (USA), Long-Term Ecological Research Program, "LTER: Biodiversity, multiple drivers of environmental change, and ecosystem functioning at the prairie forest border", 2013-2018 [D Tilman, S Hobbie, P Reich, E Seabloom], $5,880,000.

National Science Foundation (USA), Long-Term Research in Environmental Biology: "LTREB: Longterm Interactions among Biodiversity, CO_2, and N in a Perennial Grassland Ecosystem", 2012-2017, [P. Reich, S. Hobbie, T. Lee, PIs], $450,000

Institute on the Environment, University of Minnesota, The Boreal Forest and Community Resilience Project, 2009-2016 [P. Reich, PI], $800,000

National Science Foundation (USA), Ecosystem Studies Program, "The Complexity of Global Change - Interactive Effects of Warming, Water Availability, CO2 and N on Grassland Ecosystem Function ", 2011-2015 [P. Reich, PI; R Montgomery, S Hobbie, co-PIs], $985,000.

U.S. Department of Energy Program for Ecosystem Research. "Warming-induced biome change at the temperate-boreal ecotone: an experimental test of key regeneration processes", 2011-2015 [P Reich, PI; R Montgomery, S Hobbie, R Rich, co-PIs], $2,520,000

USDA AFRI, "Climate warming of the southern boreal forest: consequences for tree-insect interactions", University of Wisconsin-Madison and University of Minnesota, 2011-2014 [R. Lindroth, K Raffa, P Reich, PIs], $500,000

Institute on the Environment, University of Minnesota, Transformational Steps In Synthesis Science, 2011-2016 [P. Reich, PI], $300,000

DOE NICCR, "Experimental warming effects on soil organic matter dynamics at the temperate-boreal forest ecotone", 2010-2011 [S Hobbie, PB Reich, R Montgomery, PIs] $117,500

U.S. Department of Energy Program for Ecosystem Research. "Warming-induced biome change at the temperate-boreal ecotone: an experimental test of key regeneration processes", 2010-2011 [P Reich, PI; R Rich, S Hobbie, R Montgomery, J Oleksyn, co-PIs], $278,000

Minnesota LCCMR (Legislative and Citizens Commission for Minnesota Resources), "Healthy Forests to Resist Invasion", 2010-2013 [P. Reich, PI; A. Pierce, co-PI], $359,000

Minnesota LCCMR (Legislative and Citizens Commission for Minnesota Resources), "Adaptive management of black ash in light of emerald ash borer invasion", 2010-2012 [A. D'Amato, PI; P. Reich, and others, co-PIs], $650,000

Wilderness Research Foundation, "Ecological Health and Change in Quetico-Superior forests", 2007-2013 [P. Reich, PI], $690,000.

Minnesota LCCMR (Legislative and Citizens Commission for Minnesota Resources), Projecting Environmental Trajectories for Energy-Water-Habitat Planning, 2009-2011 [P. Reich, PI; C Lehman, and others, co-PIs], $180,000

Minnesota Department of Natural Resources, Will an exotic woody invader be more aggressive under climate warming? 2008-2010, [P. Reich, PI], $75,000

Department of Energy (USA), Sustainable pathways to achieving biofuel policy goals, 2008-2010, [S. Suh, PI; S Taff, P Reich, co-PIs], $715,340

National Science Foundation (USA), Advancing Theory in Biology: "Combining Theories For Plant Architecture, Allometry, and Traits to Develop the Next Generation of Scaling Theory", 2008-2010, [B. Enquist, P. Reich, V. Savage, J. Sperry, PIs], $737,521

MN Power, Assessment of carbon flows associated with forest management and biomass procurement for the Laskin biomass facility. [A.R. Ek, D.R. Becker, C.R. Blinn, D. Current, T.E. Burk, A.W. D'Amato, M.A. Kilgore, H.M. Hoganson, P.B. Reich, G.M. Domke, and S. Suh, PIs] ($49,428). 4/2008-12/2008.

Minnesota LCCMR (Legislative and Citizens Commission for Minnesota Resources), Climate change and CO_2 affect prairie/forest production, 2008-2010 [P. Reich, PI; C Lehman, and others, co-PIs], $330,000, 2008-2010

Minnesota LCCMR (Legislative and Citizens Commission for Minnesota Resources), Future of Minnesota's Energy and Water Resources, 2008-2010 [S. Suh, PI; P Reich, A Kapuscinski, and others, co-PIs], $270,000, 2008-2010

Australia Research Council, Plant ecological strategies across species and an evolutionary-ecology vegetation model, 2008-2010, [M. Westoby, PI; U. Dieckmann, C. Prentice, P. Reich, cooperating investigators), $AU 968,000

Australia Research Council, The physiological ecology of forest succession: explaining shade tolerance variation in evergreen and deciduous trees, 2008-2010, [C. Lusk, U. Niinemets, P. Reich, PIs], $AU 180,000

National Science Foundation (USA), Long-Term Ecological Research Program, "Biodiversity, Environmental Change and Ecosystem Functioning at the Prairie-Forest Border", 2007-2012 [D. Tilman, P. Reich and other co-PIs], $4,920,000.

U.S. Department of Agriculture. Microbial Observatory: A Genomics-enabled FACE Microbial Observatory: Changes in Microbial Diversity and Functions in responding to elevated CO, Nitrogen Deposition and Plant Diversity**,** $859,000, 2008-2010 [J. Zhou, L. Kellogg, Z. He, PIs, U. of Oklahoma; Reich is a collaborator and sub-contractor]

U.S. Department of Energy Program for Ecosystem Research. "Warming-induced biome change at the temperate-boreal ecotone: an experimental test of key regeneration processes", 2007-2011 [P Reich, PI; R Rich, S Hobbie, R Montgomery, J Oleksyn, co-PIs], $1,806,000

National Science Foundation (USA), Long-Term Research in Environmental Biology: "LTREB: Longterm Interactions among Biodiversity, CO_2, and N in a Perennial Grassland Ecosystem", 2007-2012, [P. Reich, S. Hobbie, T. Lee, PIs], $450,000

National Institute for Climate Change Research, "Interactions of water, CO_2 and N in an experimental model system", 2006-11 [P. Reich PI], $620,000.

College of Food, Agricultural, and Natural Resources Sciences, University of Minnesota, "An Integrated Initiative on Climate Change in Northern Forests", 2007-2009, [P. Reich, R. Rich, R. Montgomery, S. Hobbie, T. Lee, and others PIs], $200,000

National Science Foundation (USA), TraitNet: Research Coordination Network for Species Traits, 2007-2012 [S. Naeem, D. Bunker, lead PIs] (Reich is a Core Participant)], $500,000.

National Science Foundation (USA), LTER ($10,000) and NESCent-NCEAS Working Group, pending ($20,000), Synthesis Working Group: "Linking phylogenetic history, plant traits, and environmental gradients to understand community organization at local and continental scales", [J. Cavender-Bares, D. Ackerly, G. Burleigh, M. Mack, R. Ree, P. Reich, PIs]

USDA National Research Institute, "Managing for complex structure and wood productivity in Great Lakes pine ecosystems", 2006-2009 [B. Palik, P. Reich, R. Montgomery, PIs], $400,000.

USDA Forest Service, "Climate change and forest productivity in the Lakes States", 2006-2008 [P. Reich, PI], $50,000.

ARC Discovery Australia Research Council. Plant species economics and strategy-dimensions of plant ecology, 2006-2007, [M. Westoby, D. Ackerly, H Cornellissen, S Diaz, D Ellsworth, P. Reich, PIs), $AU 400,000

Bush Foundation, "University of Minnesota Ecosystem Science and Sustainability Initiative", 2006-2008 [A. Kapuscinski, P. Reich, D. Tilman, PIs], ($600,000)

National Science Foundation (USA), Biocomplexity Program, "Interacting responses of C and N cycles to altered biodiversity, elevated CO_2, and N enrichment", 2003-2007 [P. Reich, S. Hobbie and others], $1,800,000.

U.S. Forest Service, "Functional responses to overstory retention and understory competition in red pine ecosystems", 2003-2007 [P. Reich], $169,000.

National Science Foundation (USA), Ecological and Evolutionary Physiology Program, "Natural Selection and Evolutionary Constraints in an Elevated CO_2 Environment", 2004-2006 [P. Tiffin, P. Reich, R. Shaw, PIs], $237,000.

National Science Foundation (USA), Major Research Instrumentation Program, "Development of the Minnesota Terrestrial Integrated Mesocosms for Biophysical and Ecophysiological Research," 2004-2006 [T.J. Griffis, J.M. Cavender-Bares, J.Y. King, M.P. Russelle, P.B. Reich, PIs] $927,418.

Bush Foundation, "University of Minnesota Ecosystem Science and Sustainability Initiative", 2004-2006 [A. Kapuscinski, P. Reich, D. Tilman, PIs], $300,000

National Science Foundation (USA), Ecosystem Program, "Linking leaf and root traits to ecosystem structure and function in a common garden study of 14 temperate tree species", 2002-2007 [P. Reich, D. Eissenstat, S. Hobbie and others], $1,080,000.

National Science Foundation (USA), Long-Term Ecological Research Program, "Biodiversity, disturbance and ecosystem functioning at the prairie-forest border", 2000-2006 [D. Tilman, P. Reich and other co-PIs], $4,200,000.

Wilderness Research Foundation, "Ecological Health and Change in Quetico-Superior forests", 2002-2007 [P. Reich, PI], $530,000.

National Science Foundation (USA), Ecology Program, "Ecological Consequences of Exotic Invaders: Interactions Involving European Earthworms and Native Plant Communities in Hardwood Forests", 2000-2004 [L. Frelich, P. Reich, PIs], $318,000

National Science Foundation (USA), Long-Term Ecological Research Program, "Schoolyard LTER Program", 1999-2004 [P. Reich and other co-PIs], $60,000.

Department of Energy, Terrestrial Ecology Program, "Interaction of biodiversity, CO_2 and soil nitrogen on ecosystem functioning", 2002-2003 [P. Reich, D. Tilman, PIs], $228,000.

U.S. Forest Service, "Links between multiple disturbance events: blow-down and fire interactions", 2001-2002 [P. Reich, L. Frelich, R. Rich, PIs] $20,000.

Wilderness Research Foundation, "Ecological Health and Change in Quetico-Superior forests", 1999-2002 [P. Reich, PI], $325,000.

National Science Foundation (USA), Ecology Program, "Temperature acclimation and adaptation of respiration in eastern deciduous forests", 1998-2001 [P. Bolstad, P. Reich, J. Vose, PIs], $375,000.

National Science Foundation (USA), Ecosystem Program, "Biodiversity and the Productivity, Stability and Sustainability of Prairie Ecosystems", 1996- 2001 [D. Tilman, P. Reich, J. Knops, PIs], $507,000.

Minnesota Department of Natural Resources,"Natural Regeneration of White Pine", 1999-2002 [L. Frelich, P. Reich, PIs], $120,000.

NASA, "Bigfoot: An Approach to Validation of EOS NPP Products", 1998-2001, [W. Cohen, T. Gower, P. Reich, D. Turner, PIs], $1,500,000 ($230,000 Minnesota portion of budget).

Department of Energy, Terrestrial Ecology Program, "Interaction of biodiversity, CO_2 and soil nitrogen on ecosystem functioning", 1999-2002 (P. Reich, D. Tilman, PIs], $1,596,000.

USDA McIntire-Stennis, Agricultural Experiment Station, "Forest Response to Environmental Change", 2000-2004 [P. Reich, PI], $80,000.

National Science Foundation (USA), Ecosystem Program, "Linking leaf and root traits to ecosystem structure and function in a common garden study of 14 temperate tree species", 2001-2002 [P. Reich, J. Oleksyn, D. Eissenstat, S. Hobbie, PIs], $49,000.

National Science Foundation (USA), Doctoral Dissertation Improvement Grants Program, "Restoration of upland white cedar in northeastern Minnesota, 1996-1998 [P. Reich, M. Cornett, L. Frelich, PIs], $9,500.

NASA, "Local Validation of Global Estimates of Biosphere Properties: A Synthesis of Scaling Methods and Results Across Several Major Biomes", 1996-97 [a multiple site/investigator project, P. Reich, P. Bolstad, PIs for Minnesota site], $27,500 (Minnesota portion of budget).

Department of Energy, Terrestrial Ecology and Global Change Program, "Interaction of biodiversity, CO_2 and soil nitrogen on ecosystem functioning", 1996-1999 (P. Reich, D. Tilman, S. Naeem, J Knops, PIs], $1,560,000.

Minnesota Department of Natural Resources, "Natural Regeneration of White Pine", 1997-1999 [L. Frelich, P. Reich, PIs], $80,000.

Wilderness Research Foundation, "Ecological Health and Change in Quetico-Superior forests", 1996-1999 [P. Reich, PI], $255,000.

National Institute for Global Environmental Change, "Measuring and Modeling Component and Whole-system CO_2 Flux at Local to Regional Scales", 1997-2000 [P. Bolstad, P. Reich, K. Davis], $390,000.

National Science Foundation (USA), Ecological and Evolutionary Physiology Program, "Biogeographic adaptation to temperature, photoperiod and CO_2 in boreal conifers", 1996-2001 [P. Reich, J. Oleksyn, M. Tjoelker, PIs], $316,000.

National Science Foundation (USA), International Programs, "Convergence and divergence in leaf traits", 1999-2000 [P. Reich, PI], $29,700.

National Council for Air and Stream Improvement, "Ecosystem management of Minnesota forests: a stand-to-landscape approach to sustainability and biodiversity in harvested and undisturbed forests", 1995-2000 [P. Reich, D. Grigal, L. Frelich, M. Bauer, PIs], $200,000.

National Science Foundation (USA), Long-Term Ecological Research Program, "Succession, biodiversity and ecosystem functioning at the prairie-forest border", 1994-2000 [D. Tilman, P. Reich and other co-PIs], $3,380,000.

National Science Foundation (USA), Ecology Program, "Mechanisms of patch maintenance in old-growth hemlock-hardwood forest ecosystems", 1995-98 [P. Reich, M. Walters, L. Frelich, K. Puettmann, PIs], $297,000.

USDA McIntire-Stennis, Agricultural Experiment Station, "Ecosystem management of Minnesota forests: an integrated stand-to-landscape approach to succession, biodiversity, structure and function in harvested and unharvested northern forests", 1995-1999 [P. Reich, M Bauer, D. Grigal, PIs], $241,000.

National Science Foundation (USA), Terrestrial Ecology and Global Change Program, "Forest change in a boreal transition region: productivity, nutrient cycling and biodiversity at multiple scales", 1995-1998 [P. Reich, D. Grigal, P. Bolstad, M Bauer, PIs], $428,000.

Minnesota Department of Natural Resources,"Restoration Ecology of White Cedar", 1994-1998 [L. Frelich, P. Reich, PIs], $40,000.

Minnesota Legislative Commission on Minnesota Resources, "Developing Quality Hardwood Forests", 1993-1995 [M. Baughman, T. Burk, P. Reich, co-PIs], $210,000.

National Academy of Sciences Scientific Exchange Program, "Air Pollution and Scots pine physiology", 1993, [P. Reich, PI], $12,100.

Wilderness Research Foundation, "Ecological Health and Change in Quetico-Superior forests", 1992-1996 [P. Reich, PI], $172,000.

National Science Foundation (USA), Presidential Young Investigator Award, "Plant ecophysiology of temperate and tropical forest systems", 1988-1994 [P. Reich, PI], $312,500.

USDA Competitive Grants, Forest Biology Program, "Post-fire ecology of red oak and competing hardwood regeneration", 1990-1993 [P. Reich, E. Kruger, S. Gower, M. Abrams, co-PIs], $129,000.

National Science Foundation (USA), "Synergistic effects of elevated CO_2 and O_3: role of interspecific differences in stomatal conductance and photosynthetic pathway", 1991-92 [P. Reich, T Givnish, J Volin, co-PIs], $80,000.

National Geographic Society, "Air Pollution in Eastern Europe: Problems and Perspectives," 1991-1992 [P. Reich, J. Oleksyn co-PIs], $24,150.

National Science Foundation (USA), Ecology Program, "Production and resource use efficiency of larch and sympatric evergreen conifers," 1991-1994 [S. Gower, P. Reich, co-PIs], $200,000.

USDA Competitive Grants, Forest Biology Program, "Seasonal carbon, water, and nitrogen relations in pine and oak forests", 1986-1989 [P. Reich, J. Fownes, co-PIs], $111,000.

USDA Competitive Grants, Forest Biology Program, "Physiological responses of conifers to sawfly attack", 1987-1990 [K. Raffa, P. Reich, co-PIs], $150,894.

National Science Foundation (USA), "Carbon and nutrient relations among oligotrophic forest communities in the north central Amazon basin", 1989-1991 [P. Reich, C. Uhl, co-PIs], $127,500.
National Council of the Paper Industry for Air and Stream Improvement, "Integrated studies of the effects of ozone pollution on forests", 1989-1993 [P. Reich, PI], $112,500.
McIntire-Stennis Program, USDA, "Effects of acid rain and heavy metal pollution on the physiology of north central forest tree species", 1986-1990 [P. Reich, PI], $77,000.
Academy of Finland, National Research Council for Agriculture and Forestry, "Factors affecting cold hardiness in forest trees", 1987-1989 [M. Sutinen, P. Reich, co-PIs], $20,000.
Graduate School, University of Wisconsin and C.W. Nave Fund for Latin American Research, "Rain forest ecophysiology in the northern Amazon Basin", 1986-1988 [P. Reich, PI], $20,465.
University-Industry Research Program, University of Wisconsin, "Physiological response of red pine trees to fertilizer and sludge treatment", 1986-1988 [P. Reich, PI], $17,465.
Graduate School, University of Wisconsin, "Photosynthesis, stomatal control of water loss, and water use efficiency during leaf aging in several tree species", 1986-1987 [P. Reich, PI], $14,682.

REVIEWER FOR

Agencies:

Ministry of the Environment (Denmark)
Environmental Protection Agency (USA)
National Aeronautics and Space Administration (USA)
Department of Energy- Terrestrial Ecology Program (USA)
Department of Energy- Carbon Cycling Program (USA)
NSF- Biocomplexity Program (USA)
NSF- Ecology Program (USA)
NSF- Ecosystems Program (USA)
NSF- Ecological and Evolutionary Physiology Program (USA)
NSF- International Program (USA)
Natural Environment Research Council (UK)
Smithsonian Institution (USA)
USDA Competitive Grants Research- Forest Biology (USA)
USDA/NRI- Plant Response to the Environment (USA)
USDA/NRI- Ecosystems Program(USA)
U.S. Forest Service (USA)
U.S. National Park Service (USA)
Simbiota (International)
Wisconsin Department of Natural Resources (USA)

Journals (ad hoc referee):

Agronomy Journal; American Naturalist; American Journal of Botany; American Midland Naturalist; Annals of Botany; Biogeochemistry; Biotropica; Can Journal of Botany; Can J of Forest Research; Climatic Change; Crop Science; Ecological Applications; Ecological Monographs; Ecology; Ecology Letters; Ecosystems; Environmental Pollution; Forest Ecology and Management, Forest Science; Functional Ecology; Global Change Biology; HortScience; Journal of Ecology; Journal of Environmental Quality; J Experimental Biology; Nature; Nature Climate Change; Nature Geoscience; Nature Plants; New Phytologist; Oecologia; Oecologia Plantarum; Oikos; Physiologia Plantarum; Plant, Cell and Environment; Plant Ecology; Plant Physiology; Proc National Academy Sciences; PLOS Biology; Remote Sensing of Environment; Science; Tree Physiology; Trees; Trends in Ecology and Evolution; Water, Air, and Soil Pollution

PRESENTATIONS AT CONFERENCES, CONGRESSES, AND RELATED (as author or co-author)

Approximately 250 (with published abstracts), 380 (in total), 1980-2013

PUBLICATIONS (Refereed, ≈490 total; ≈ 470 journal articles, ≈25 book chapters and other)

2015

Ali, A, BE Medlyn, T Aubier, KY Crouse, PB Reich. Elevated carbon dioxide is predicted to promote coexistence among competing species in a trait-based model. Ecology & Evolution (in press).

Ali, A, C Xu, A Rogers, NG McDowell, BE Medlyn, RA Fisher, S Wullschleger, PB Reich et al, 2015. Global scale environmental control of plant photosynthetic capacity. Ecological Applications (in press)

Atkin, OK, KJ Bloomfield, PB Reich, MG Tjoelker, *et al*. 2015. Global variability in leaf respiration among plant functional types in relation to climate and leaf traits. New Phytologist 206(2): 614-636.

Cardinale B, PB Reich et al 2015. Functional Ecology

Cesarz, S, PB Reich, S Scheu, L Ruess, M Schaefer, N Eisenhauer. 2015. Nematode functional guilds, not trophic groups, reflect shifts in soil food webs and processes in response to interacting global change factors. Pedobiologia 58:23-32.

Davidson, M, Jewell, B Shipley, A Paquette, C Messier, PB Reich. 2015. A traits-based test of the home-field advantage in mixed-species 3 tree litter decomposition. Annals of Botany (in press)

Deng, Ye; He, Zhili; Xiong, Jinbo; Yu, Hao; Xu, Meiying; Hobbie, Sarah; Reich, Peter B; Schadt, Chris; Kent, Angela; Pendall, Elise; Wallenstein, Matthew; Zhou, Jizhong. Elevated carbon dioxide accelerates the spatial turnover of soil microbial communities. Global Change Biol (in press)

Drake, JE, MJ Aspinwall, S Pfautsch, PD Rymer, PB Reich, RA Smith, KY Crous, DT Tissue, Ghannoum, MG Tjoelker. 2015. The capacity to cope with climate warming declines from temperate to tropical latitudes in two widely distributed *Eucalyptus* species. Global Change Biology 21:459-472.

Drake, JE, MG Tjoelker, PB Reich and others. Carbon cycling responses of a mature eucalypt woodland to gradual stepwise enrichment of atmospheric CO_2 concentration. Global Change Biology (in press)

Feng, Z, T Rütting, H Pleije, G Wallin, PB Reich, CI Kammann, PCD Newton, K Kobayashi, Y Luo, J Uddling. 2015. Constraints to Nitrogen Acquisition of Terrestrial Plants under Elevated CO_2. Global Change Biol (in press)

Hautier, Y, D Tilman, F Isbell, EW Seabloom, ET Borer, PB Reich. 2015. Anthopogenic environmental changes impact ecosystem stability via biodiversity. Science 348:336-340, doi: 10.1126/science.aaa1788

Isbell F, D Craven, J Connolly, M Loreau, B Schmid, C Beierkuhnlein, T. Martijn Bezemer8, C Bonin, H Bruelheide2, E de Luca, A Ebeling, J Griffin, Q Guo, Y Hautier, A Hector, A Jentsch, J Kreyling, V Lanta, P Manning, ST Meyer, AS Mori, S Naeem, PA Niklaus, HW Polley, PB Reich, C Roscher, EW Seabloom, MD Smith, MP Thakur, D Tilman, BF Tracy, WH van der Putten, J van Ruijven, A Weigelt, WW Weisser, B Wilsey, N Eisenhauer. Biodiversity increases the resistance of ecosystem productivity to climate extremes. Nature (in press)

Jamieson, MA, EG Schwartzberg, KF Raffa, PB Reich, RL Lindroth. 2015. Experimental climate warming alters aspen and birch phytochemistry and performance traits for an outbreak insect herbivore. Global Change Biology DOI: 10.1111/gcb.12842

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