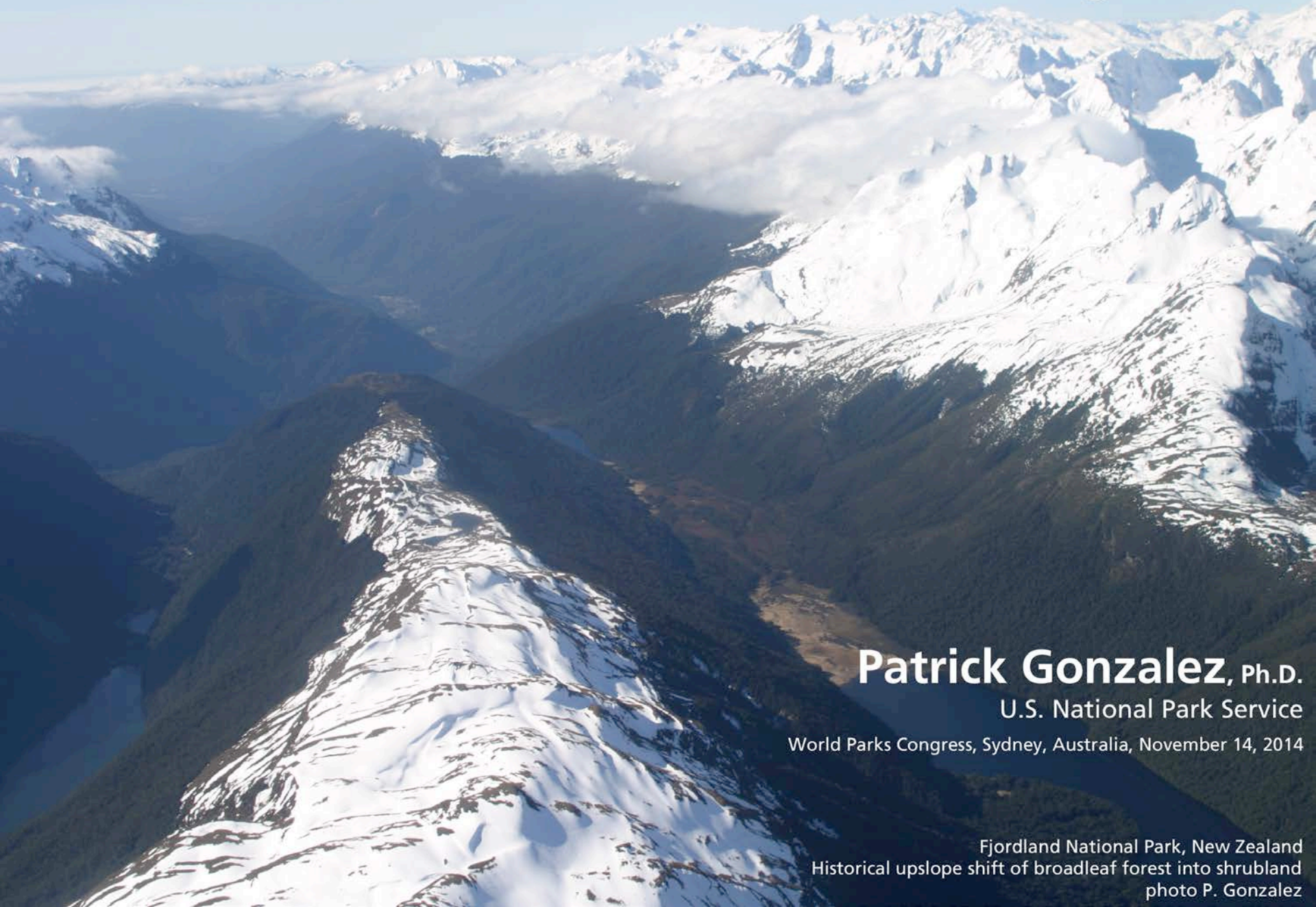


# Global Biome Shifts due to Climate Change



**Patrick Gonzalez, Ph.D.**

U.S. National Park Service

World Parks Congress, Sydney, Australia, November 14, 2014

Fjordland National Park, New Zealand  
Historical upslope shift of broadleaf forest into shrubland  
photo P. Gonzalez



# Global Biome Shifts Due to Climate Change

## Outline

1. Vegetation biomes
2. Historical biome shifts
3. Future vulnerabilities
4. Protected area management implications

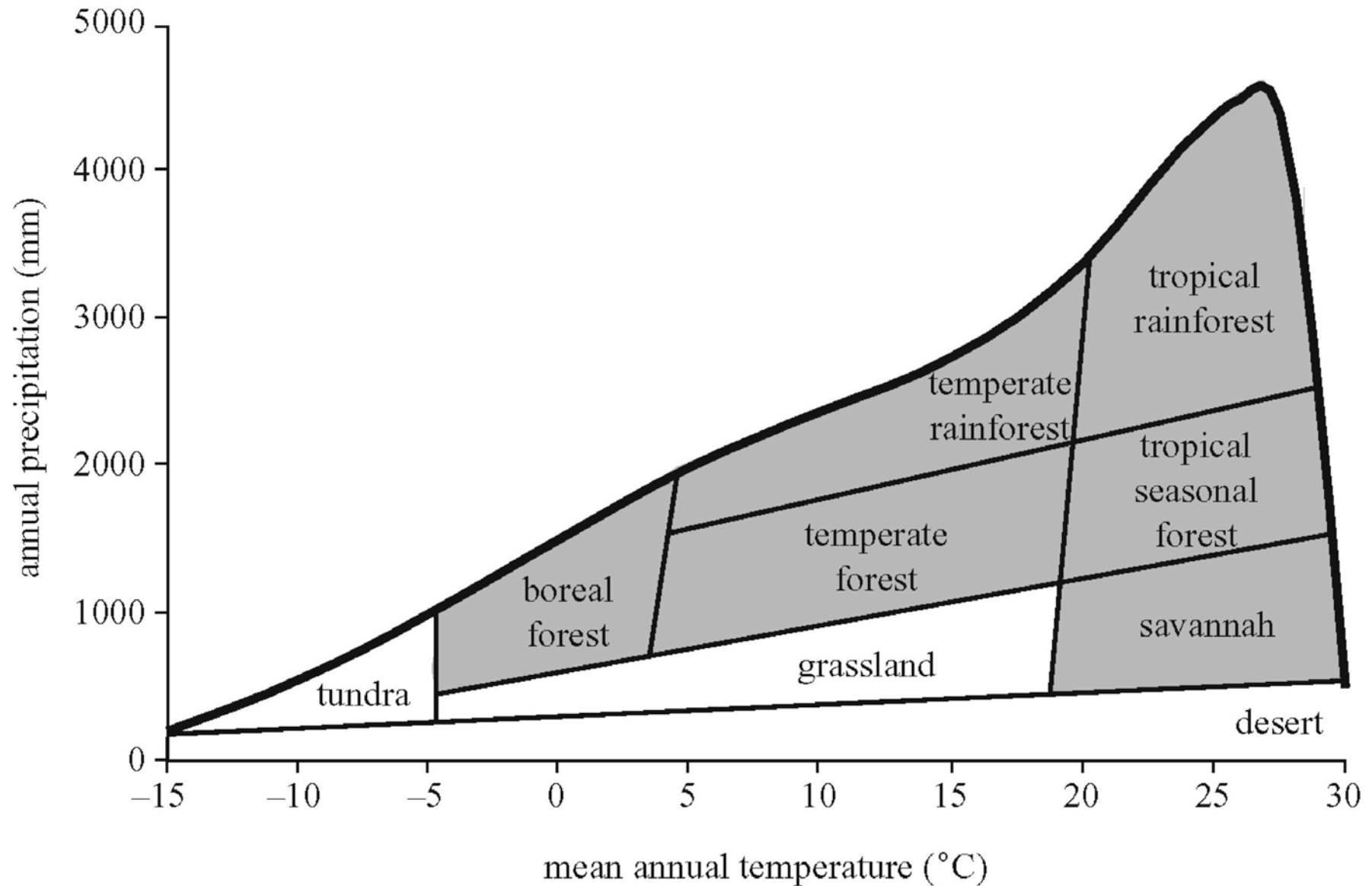


# Global Biome Shifts Due to Climate Change

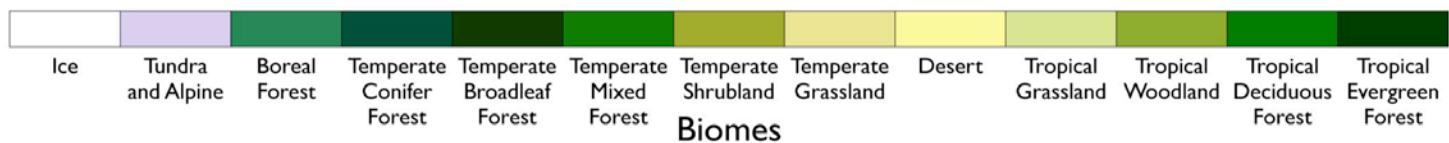
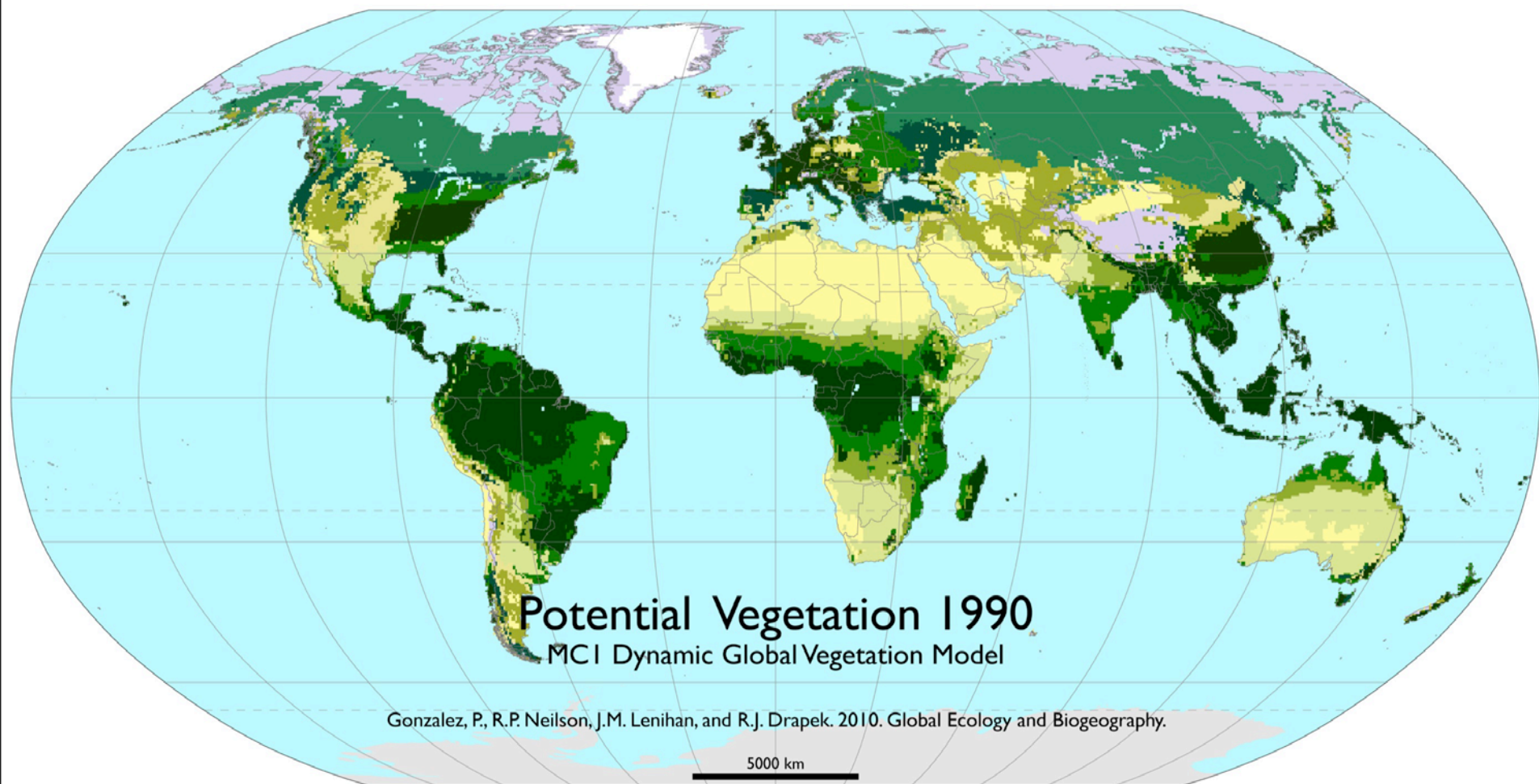
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# A Biome is a Major Vegetation Zone Dominated by a Distinctive Plant Form

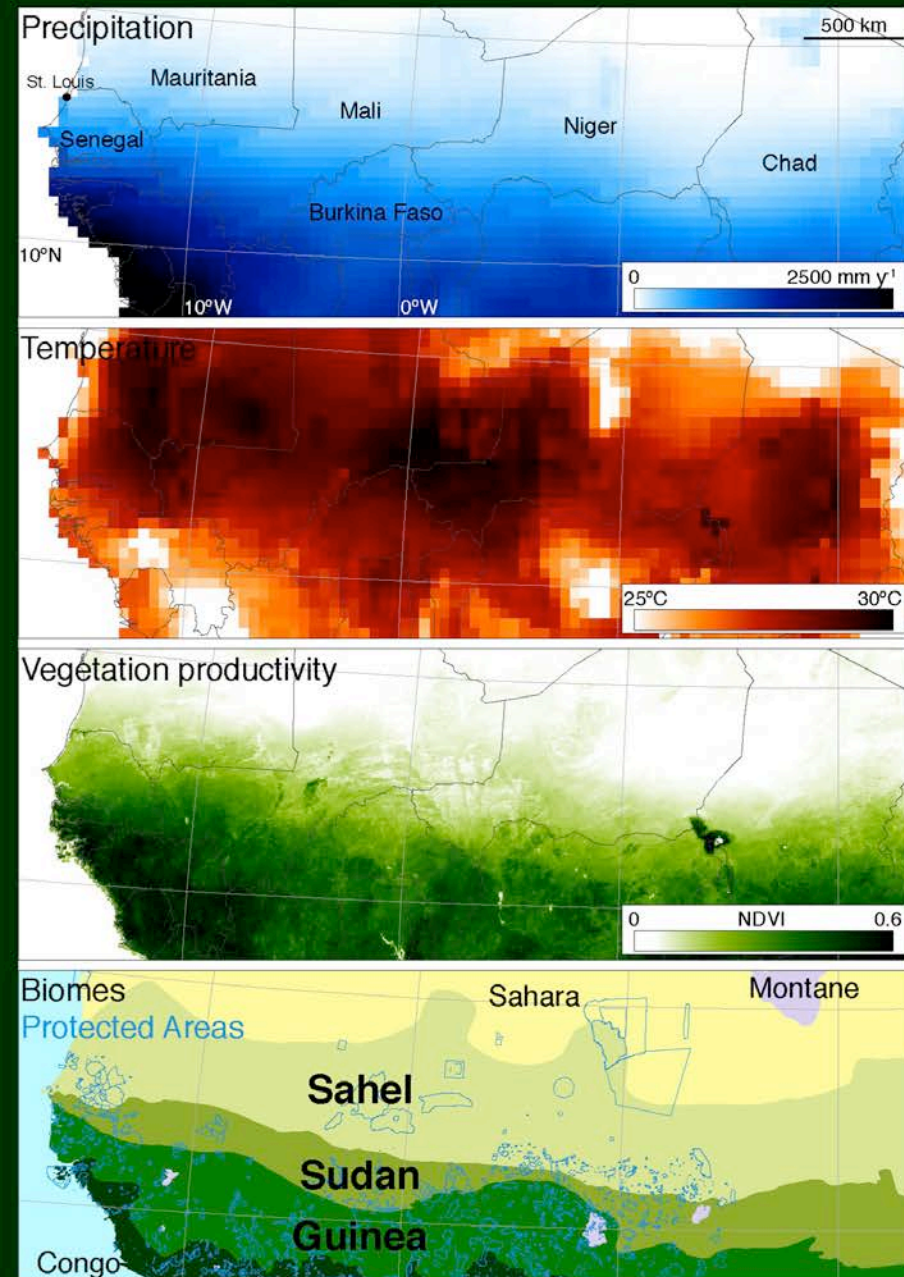








# Biomes of West Africa



Data Gonzalez et al. 2012 Journal of Arid Environments

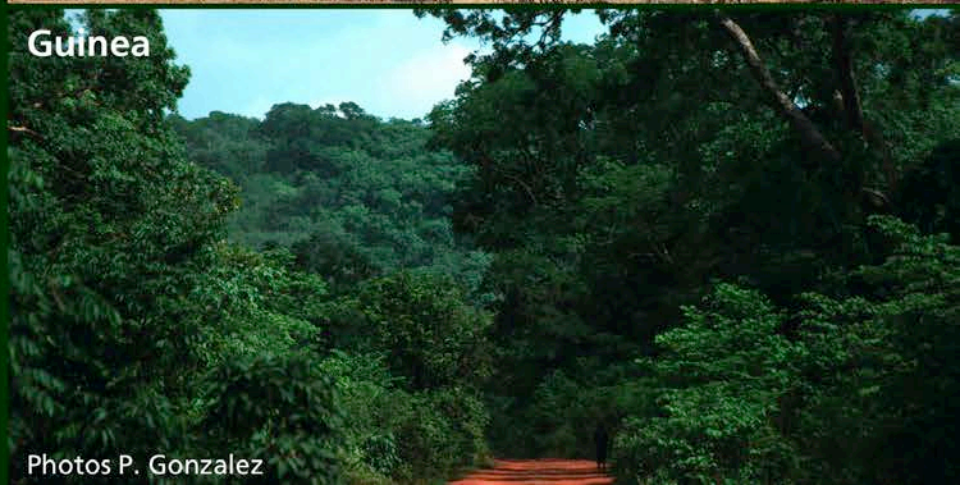
## The Sahel



## Sudan



## Guinea



Photos P. Gonzalez



# Biomes of the Sierra Nevada, California, USA

Mount Whitney, elevation 4417 m  
Highest Point in the lower 48 United States

Alpine

Boreal Conifer Forest

Temperate Conifer Forest

Temperate Broadleaf Forest

Temperate Shrubland

Sequoia National Park  
Inyo National Forest  
Alabama Hills Recreation Lands  
California, USA  
photo P. Gonzalez



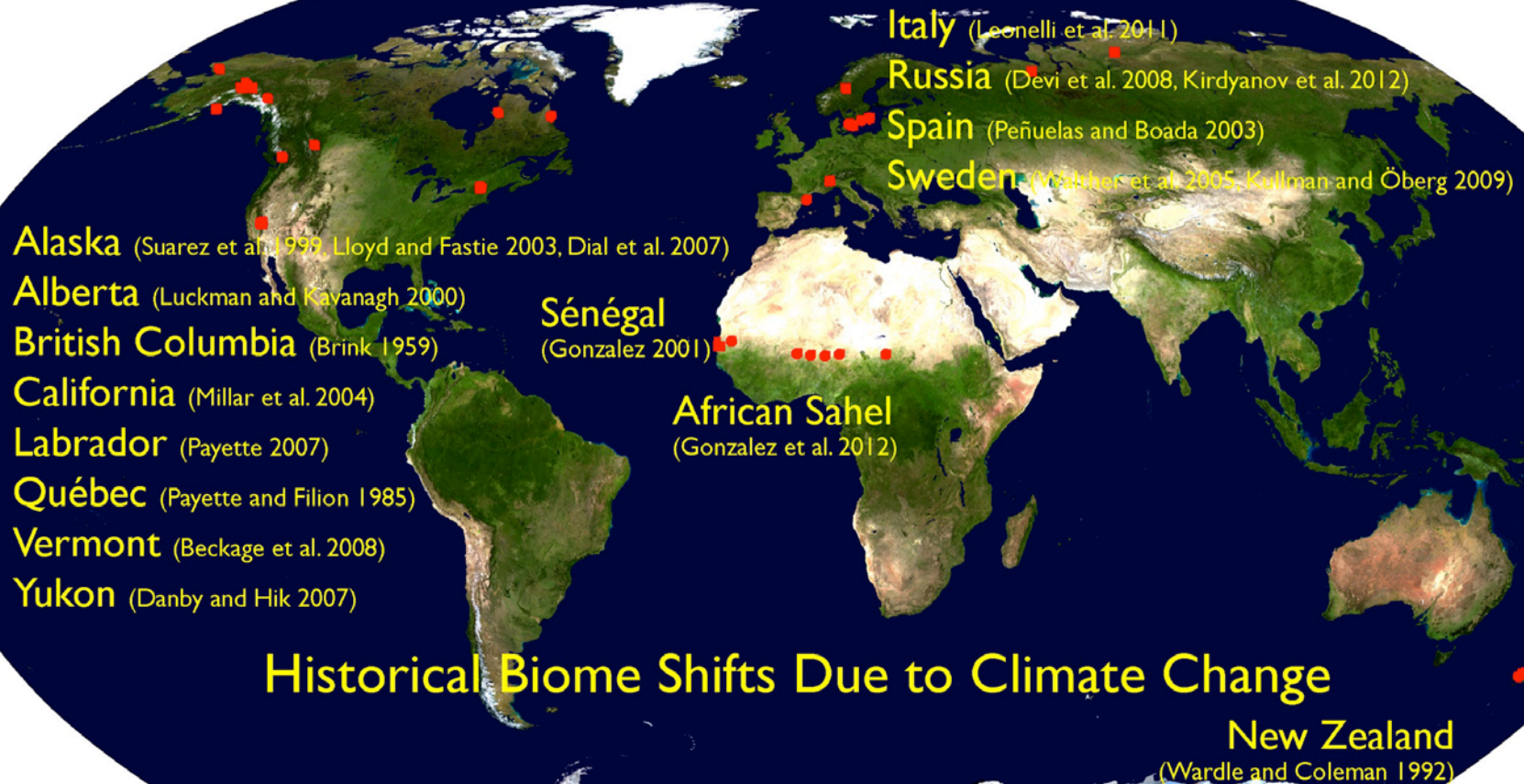


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## Historical Biome Shifts Due to Climate Change

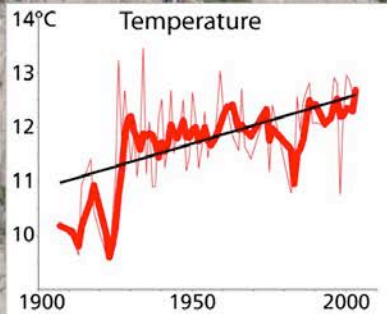
Analysis: Gonzalez et al. 2010 Global Ecology and Biogeography,  
Settele et al. 2014 Intergovernmental Panel on Climate Change  
Satellite Image: National Aeronautics and Space Administration





# Climate change has shifted subalpine forest upslope into alpine meadows in Yosemite National Park, USA

Millar et al. 2004 Arctic, Antarctic, and Alpine Research



Yosemite National Park, California, USA  
photo P. Gonzalez





# Climate change has shifted boreal forest into tundra in Noatak National Preserve, USA

Suarez et al. 1999 Ecoscience





# Climate change has shifted temperate broadleaf forest upslope into sub-alpine shrubland in Fjordland National Park, New Zealand

Wardle and Coleman 1992 New Zealand Journal of Botany



Fjordland National Park, New Zealand  
photo P. Gonzalez



# Climate change has shifted temperate broadleaf forest upslope into alpine heathland in the Parc Natural del Montseny, España

Peñuelas and Boada 2003 Global Change Biology



Parc Natural del Montseny, España  
photo Antonio Velez



# Climate change has shifted the Sahel savanna and Sudan woodland biomes south in the Réserve Sylvo-Pastorale des Six Forages, Sénégal

Gonzalez et al. 2012 Journal of Arid Environments



Réserve Sylvo-Pastorale des Six Forages, Sénégal  
photo P. Gonzalez





# Global Biome Shifts Due to Climate Change

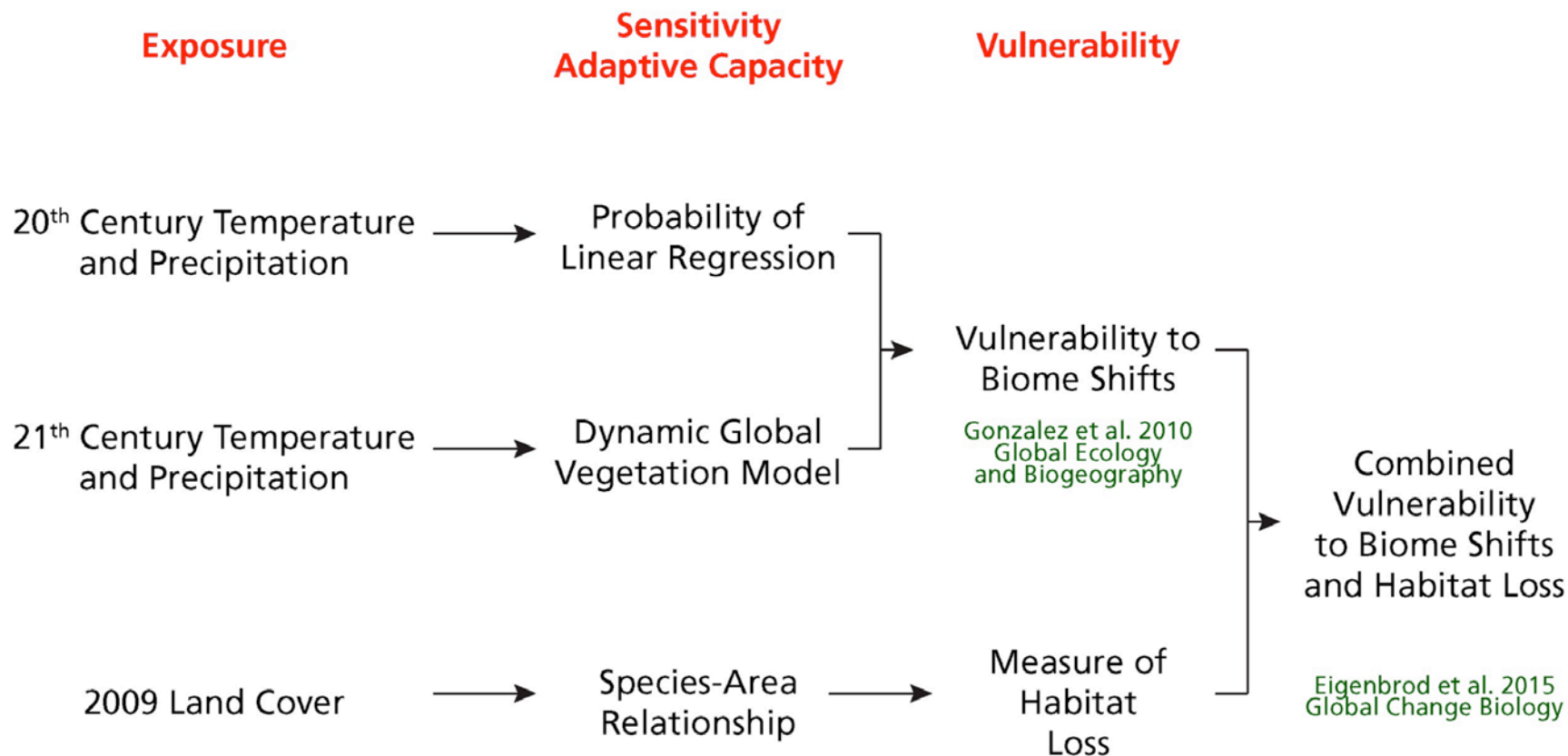
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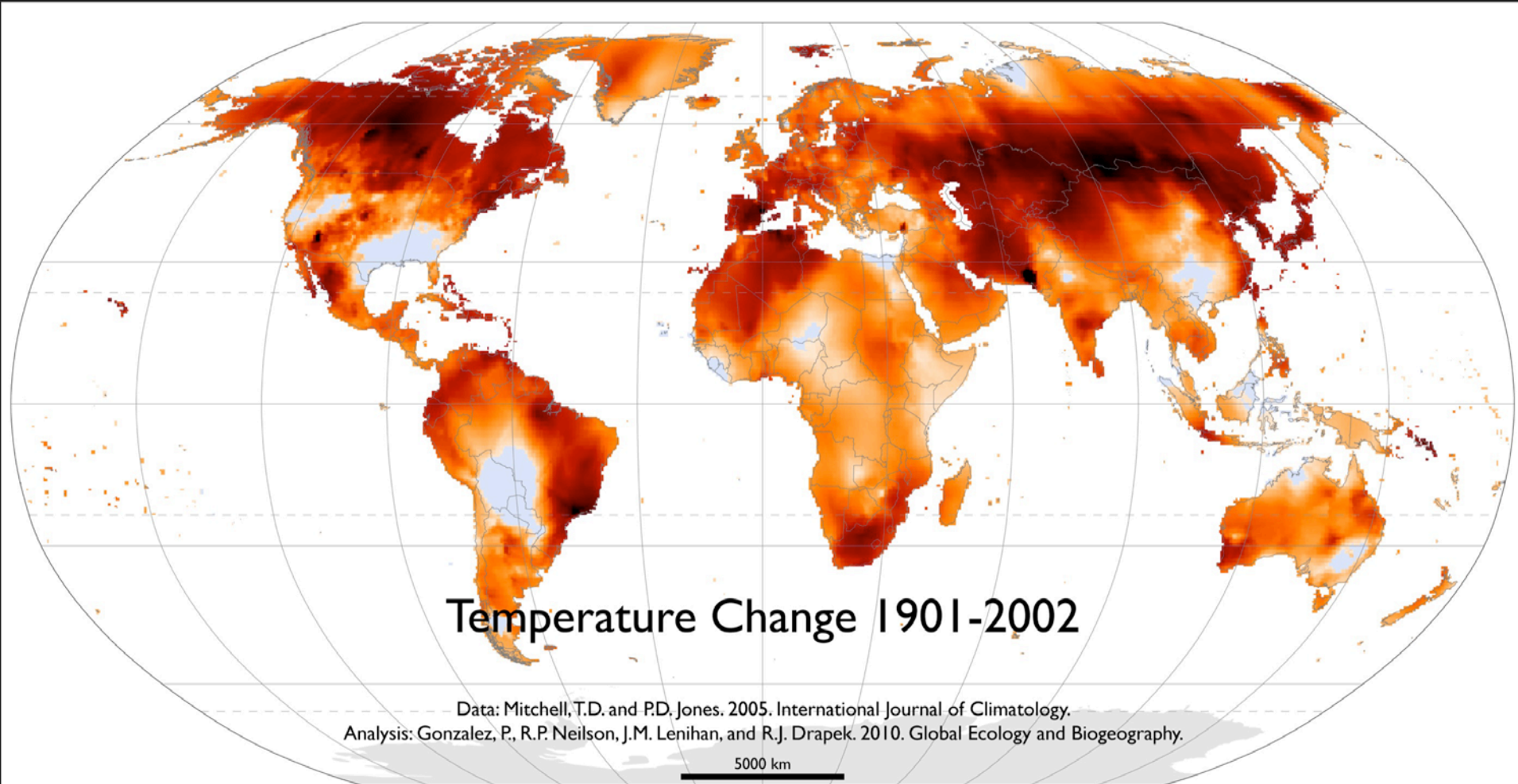




## Vulnerability of Ecosystems to Biome Shifts Due to Climate Change and Habitat Loss Due to Land Cover Change





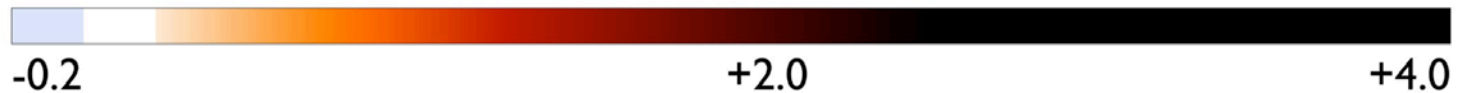


## Temperature Change 1901-2002

Data: Mitchell, T.D. and P.D. Jones. 2005. International Journal of Climatology.

Analysis: Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2010. Global Ecology and Biogeography.

5000 km

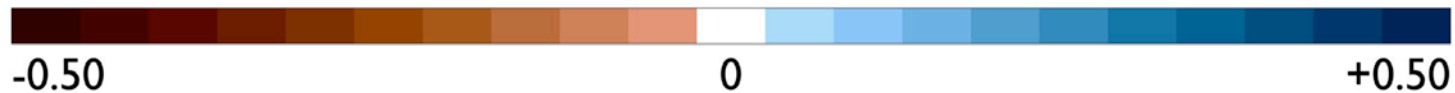
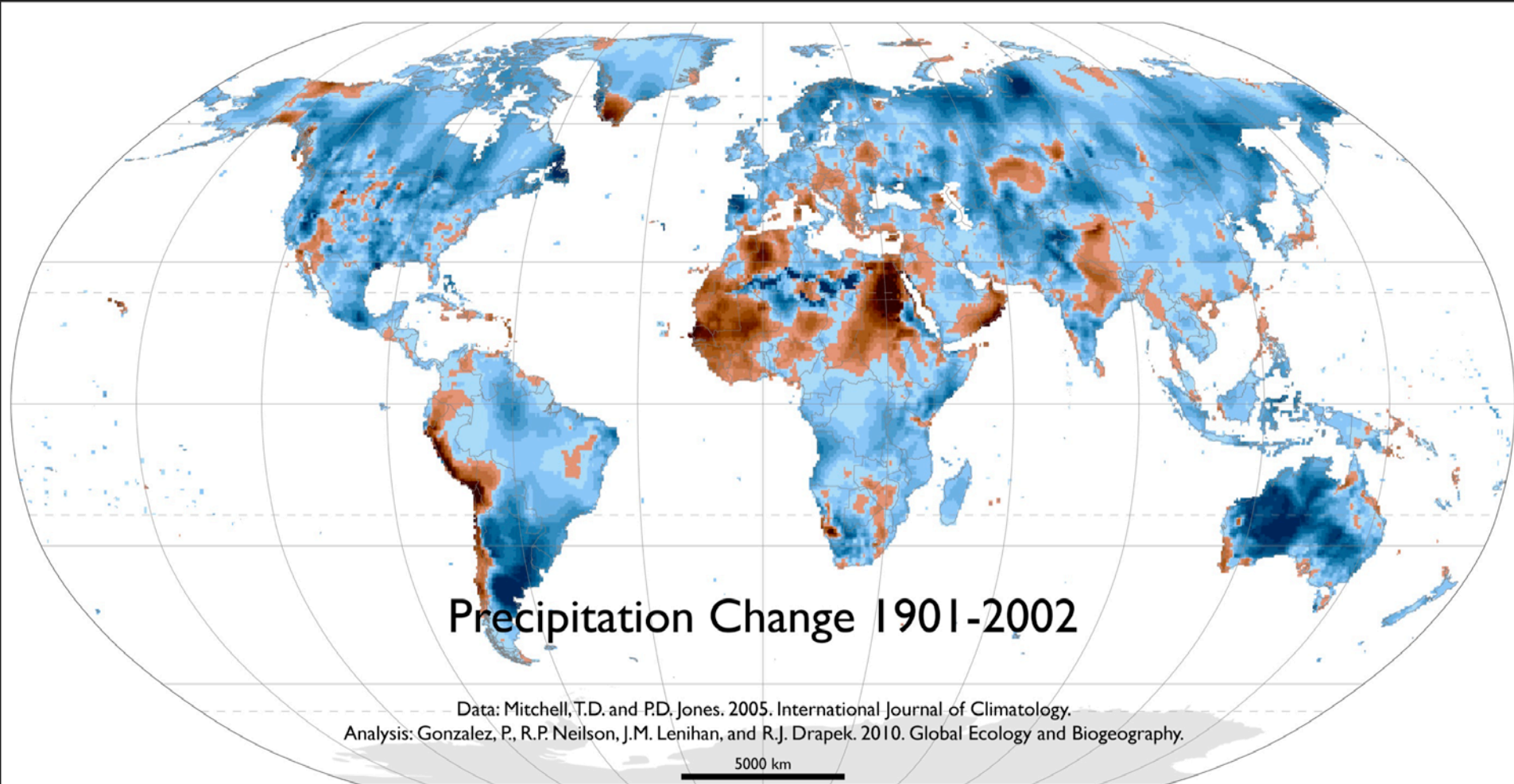


-0.2

+2.0

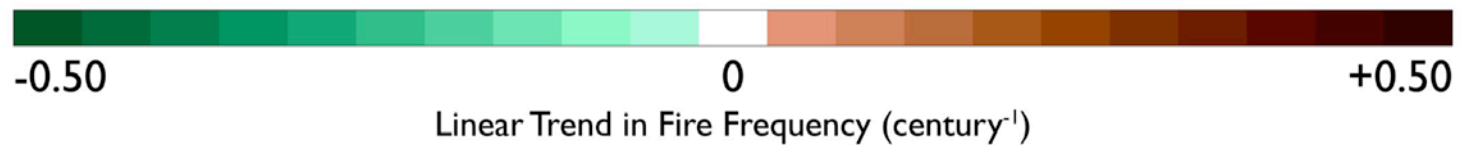
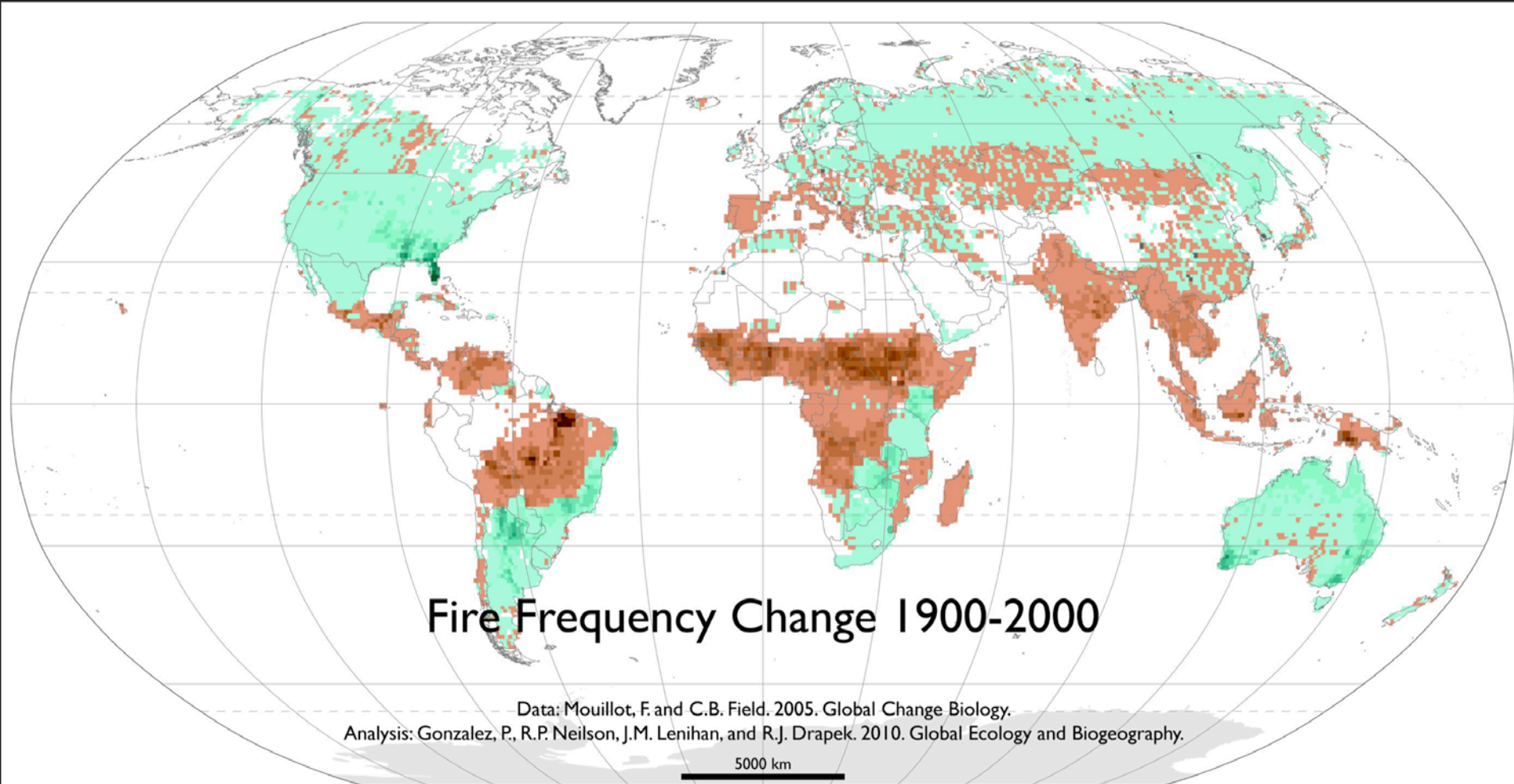
+4.0

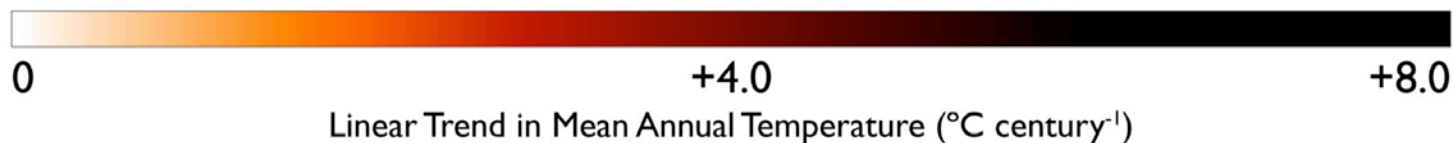
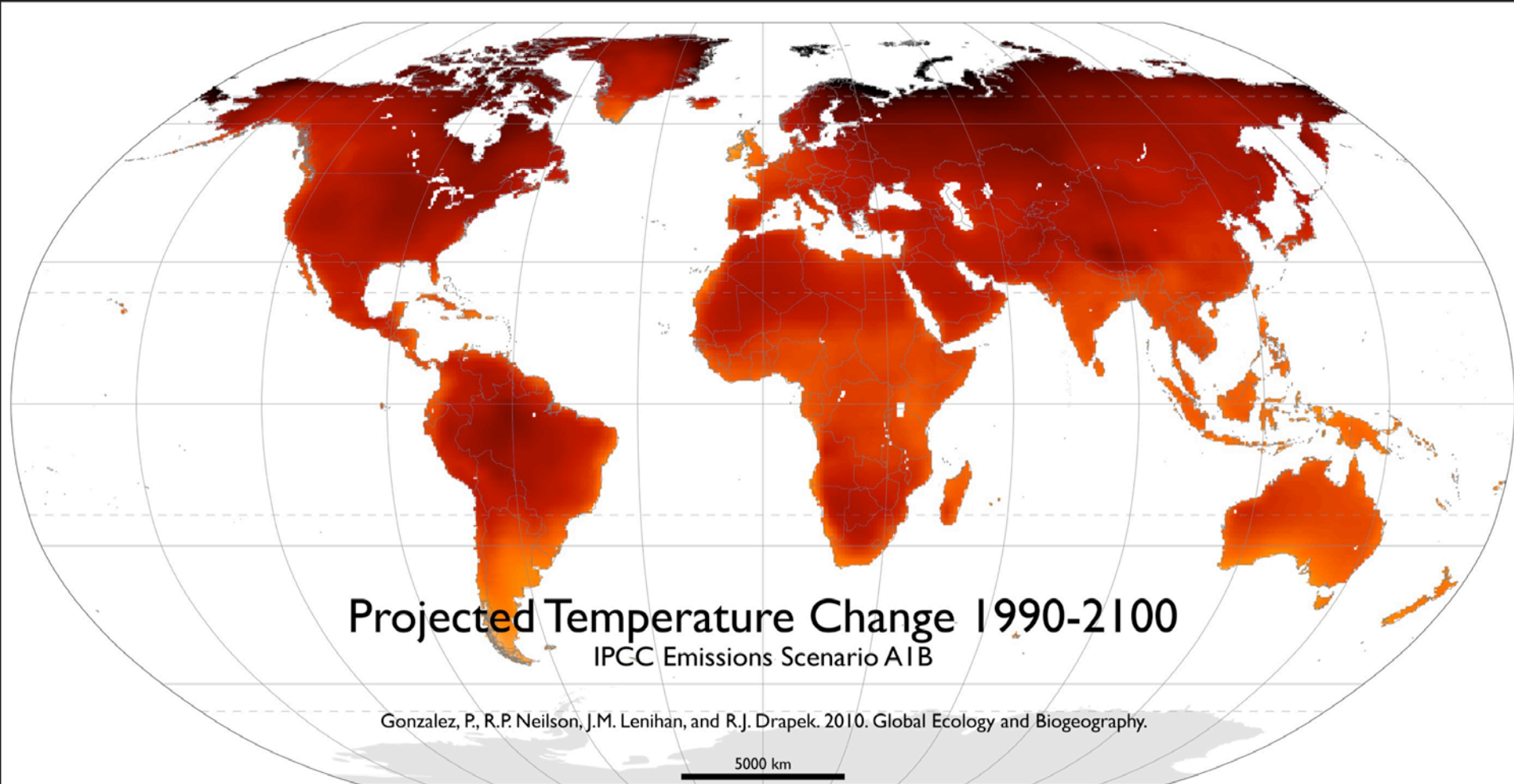
Linear Trend in Mean Annual Temperature ( $^{\circ}\text{C century}^{-1}$ )



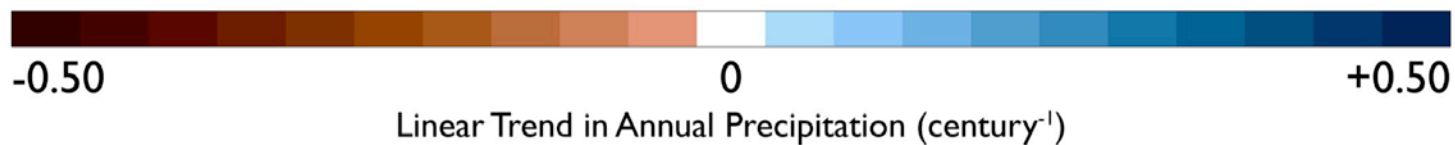
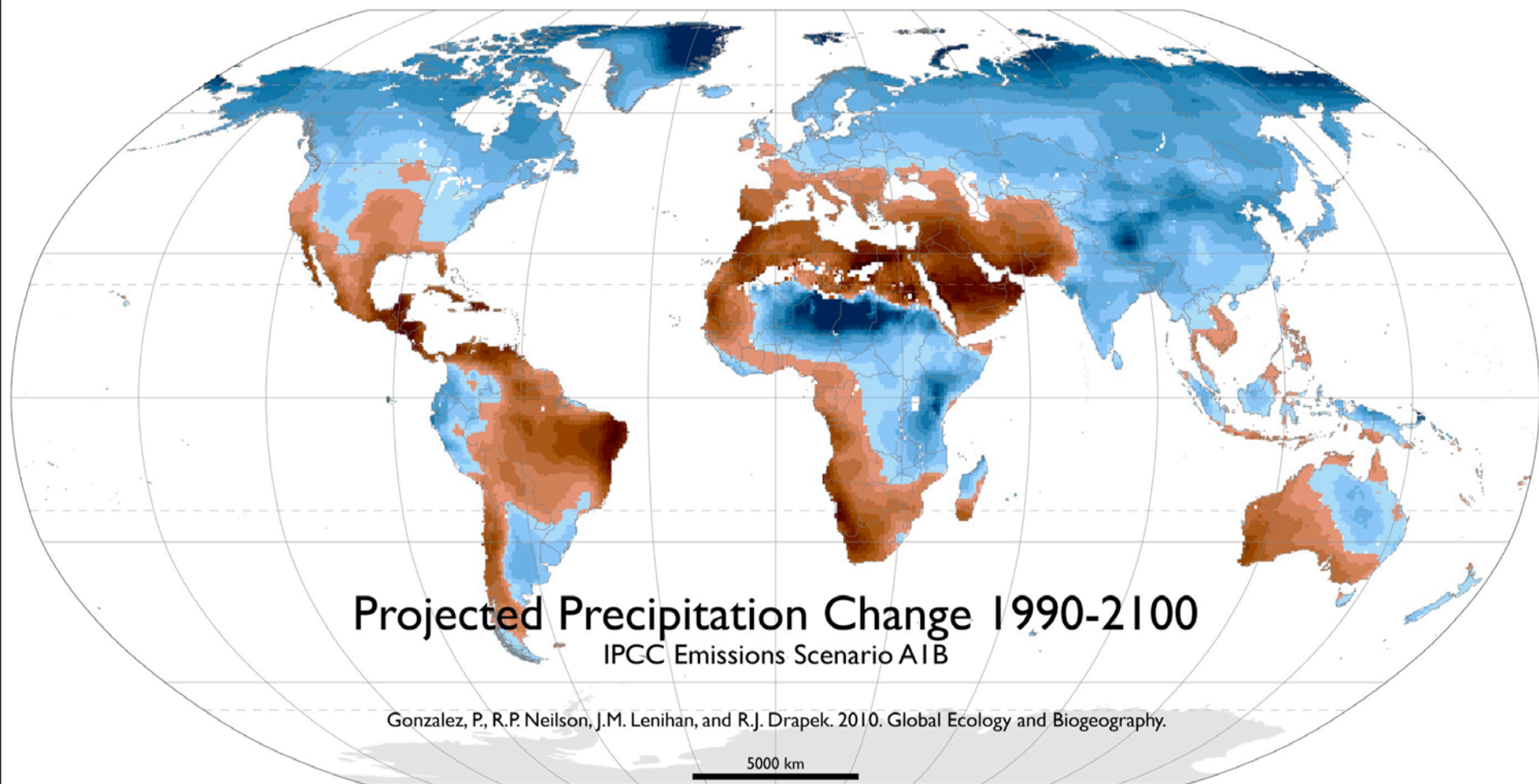
Linear Trend in Annual Precipitation (century<sup>-1</sup>)





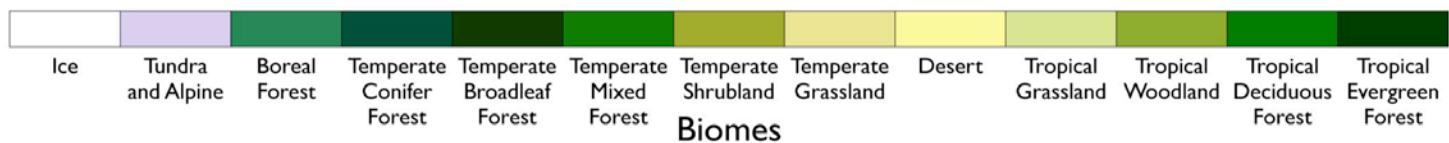
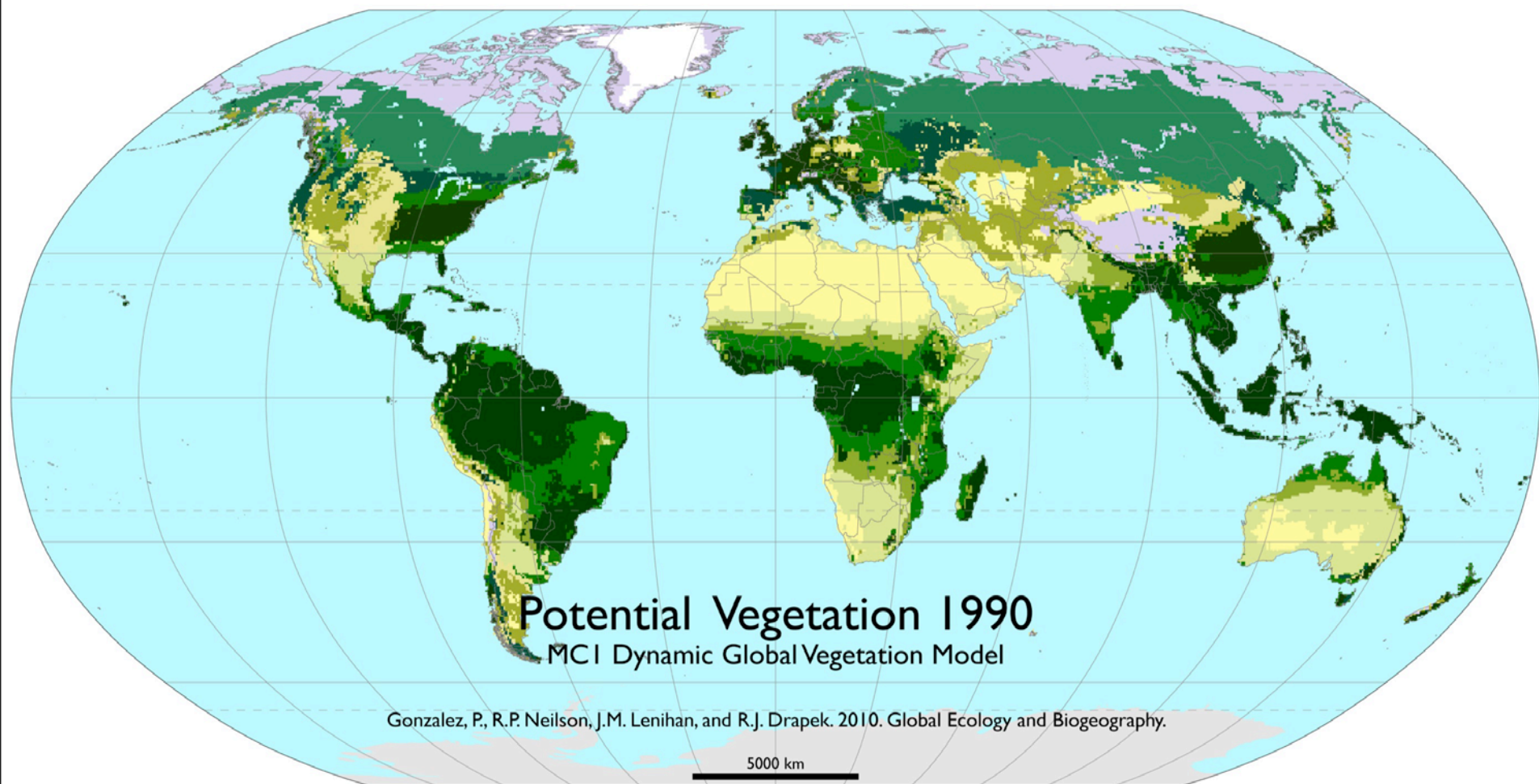


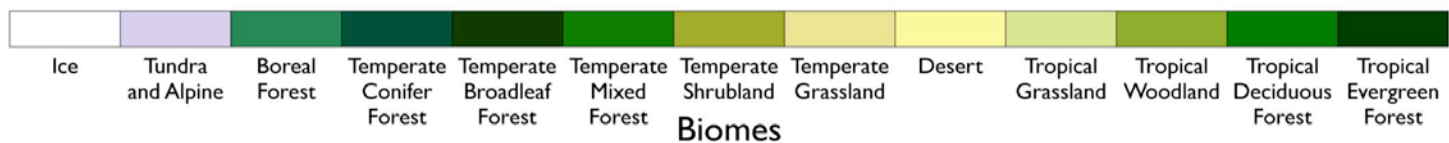
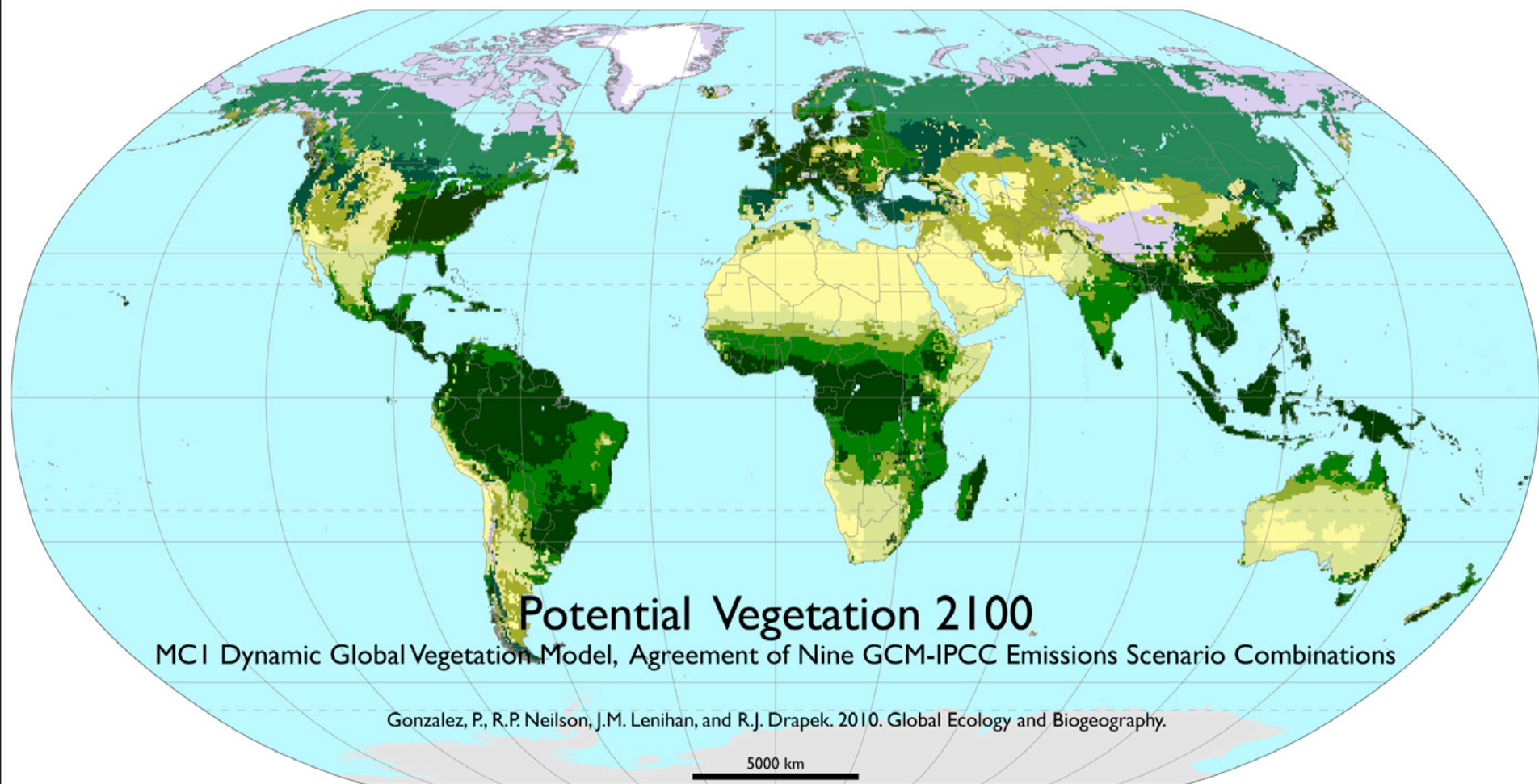




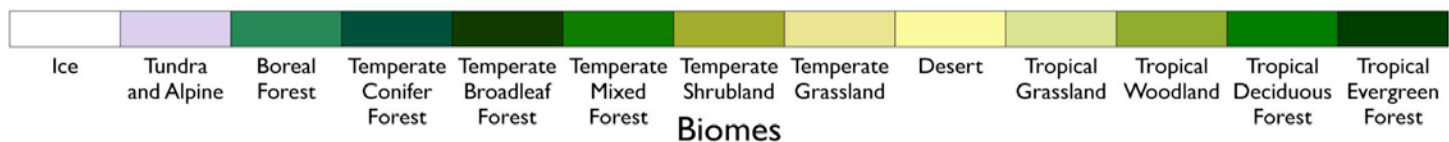
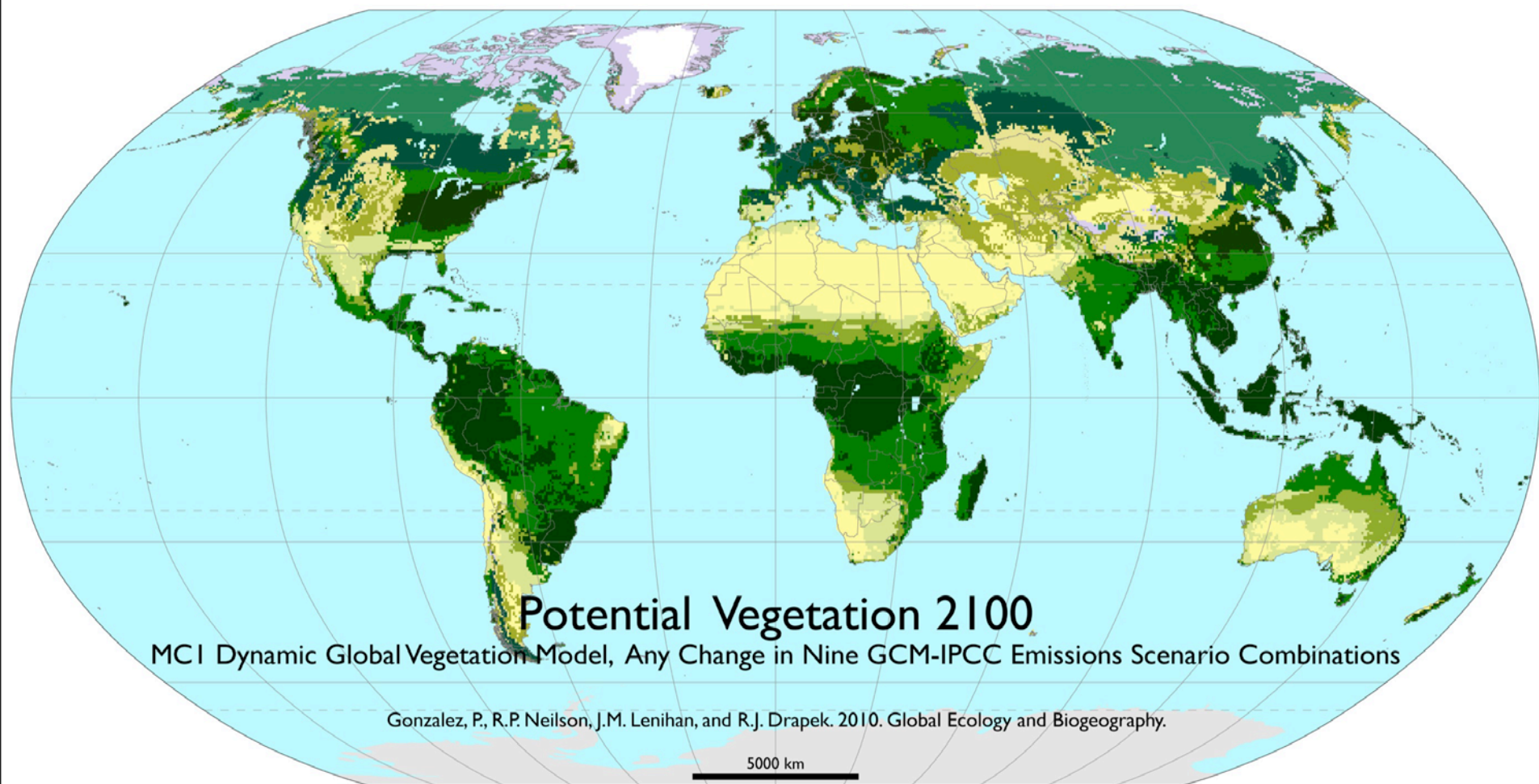


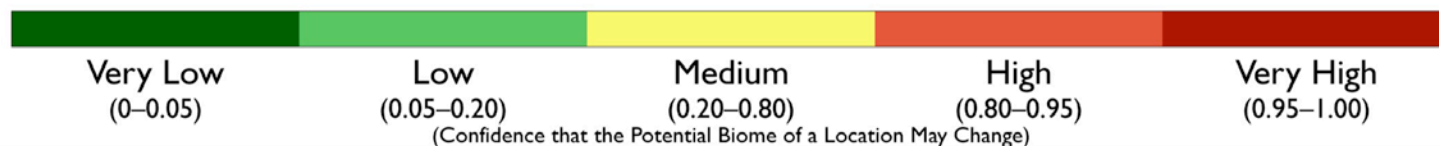
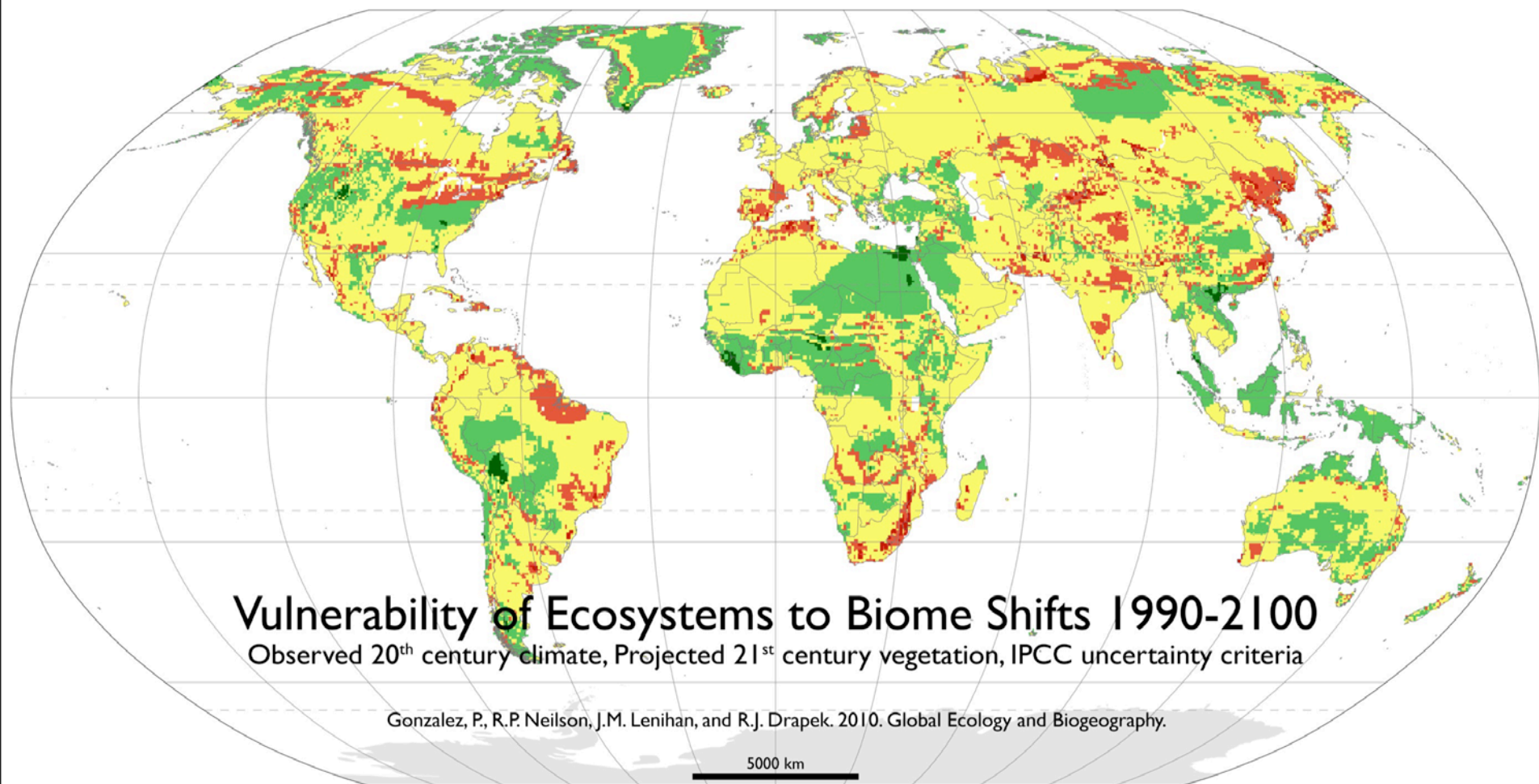




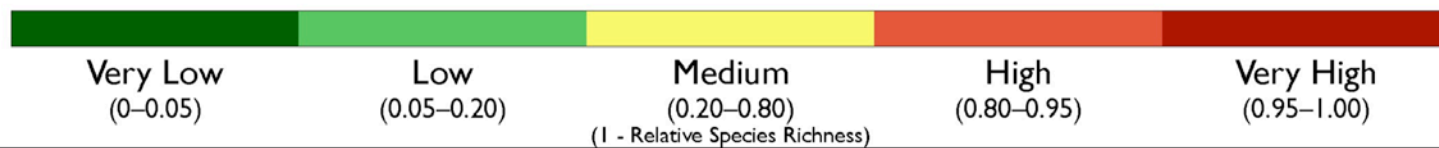
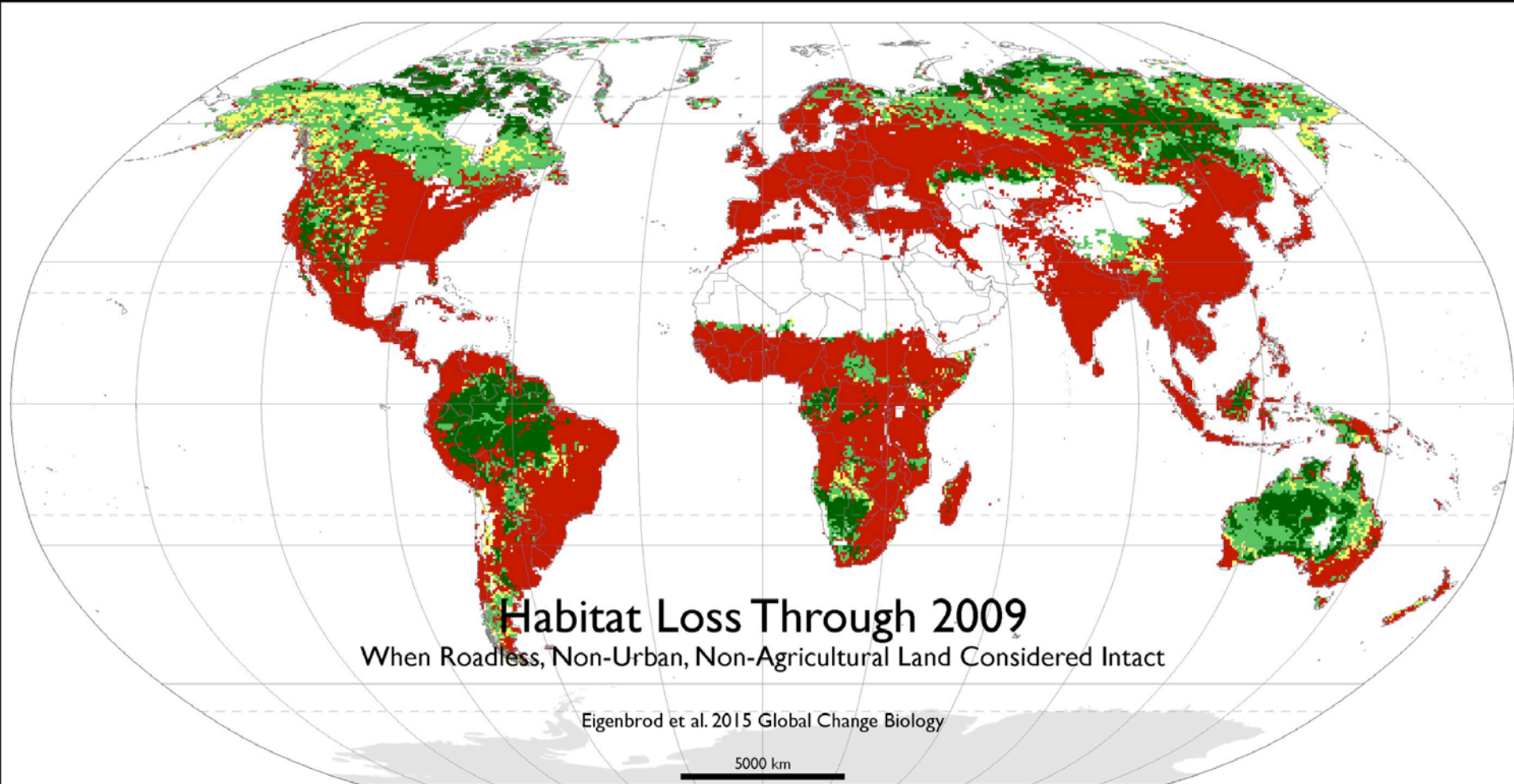


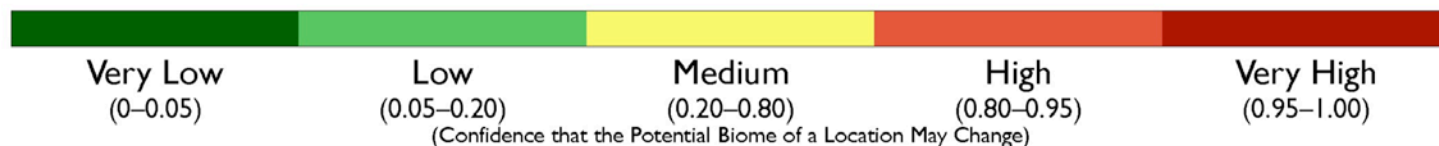
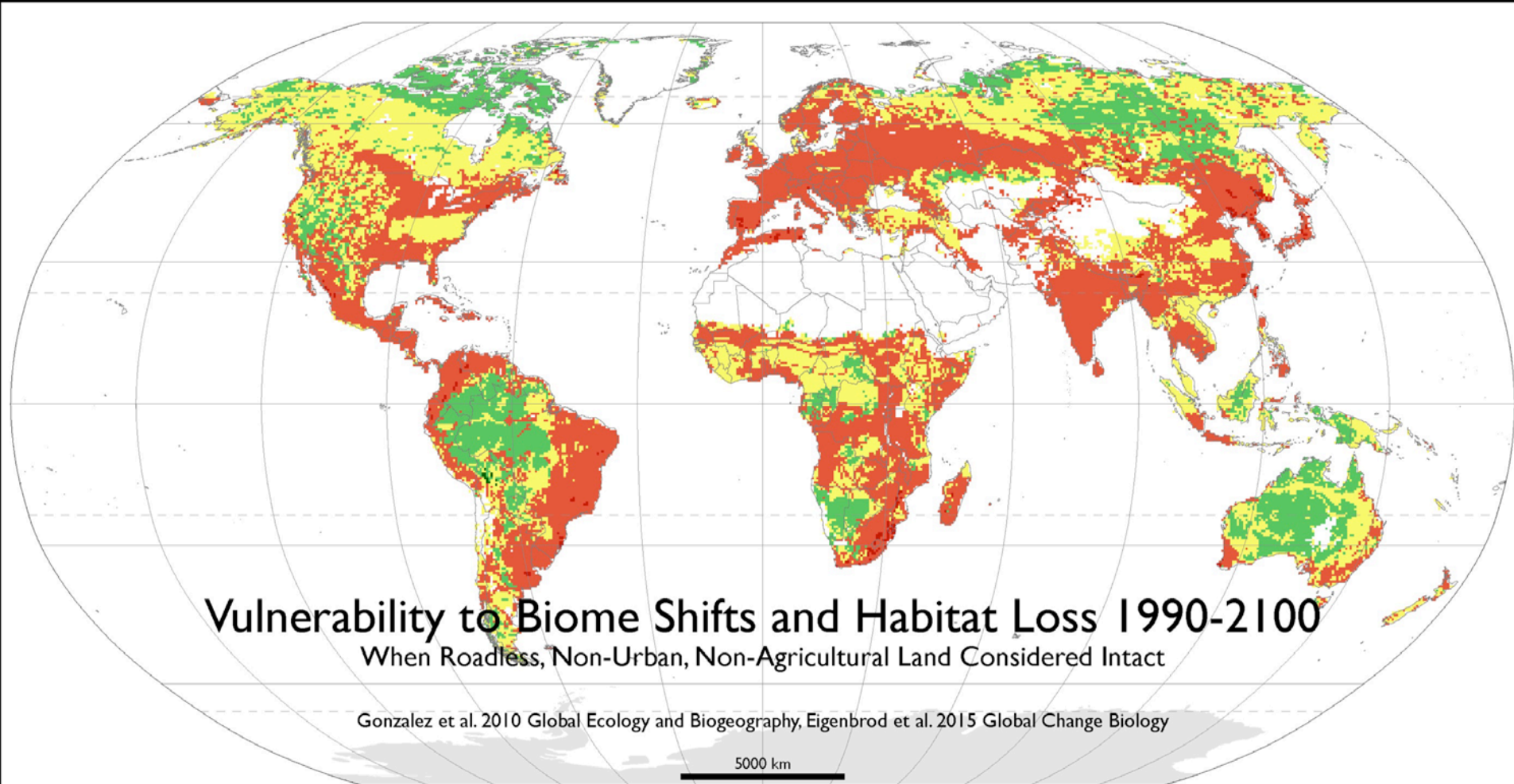












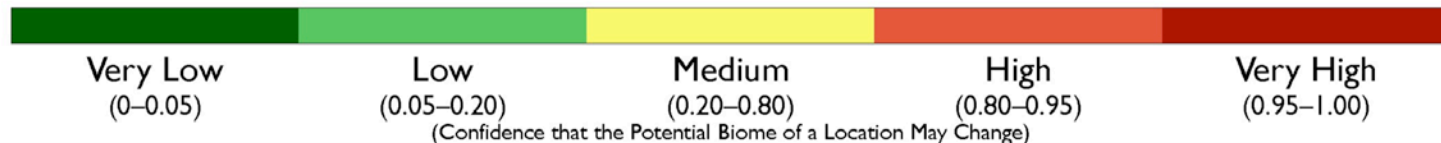


# Vulnerability to Biome Shifts and Habitat Loss 1990-2100

When Only Protected Areas are Considered Intact

Gonzalez et al. 2010 Global Ecology and Biogeography, Eigenbrod et al. 2015 Global Change Biology

5000 km



# Highly Vulnerable: Temperate Mixed Forests



Cape Breton Highlands National Park, Canada  
photo P. Gonzalez





# Highly Vulnerable: Temperate Broadleaf Forest





# Highly Vulnerable: Tropical Woodlands





# Potential Refugia to Biome Shifts: Tropical Rainforests

Parc National de Masoala, Madagascar  
photo P. Gonzalez



# Potential Refugia to Biome Shifts: Deserts



Uluru  
Uluru-Kata Tjuta National Park, Australia  
photo P. Gonzalez





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Local people  
depend on many  
tree species  
reduced by  
biome shifts due  
to climate change

Gonzalez 2001 Climate Research



Drying berries of siddéem (jujubes, *Zizyphus mauritiana*)  
Vicinity of the Forêt Classée de Diamel, Sénégal  
photo P. Gonzalez



# Biome shifts species turnover can exacerbate ecosystem vulnerability to invasive species due to climate change

Mooney and Hobbs 2000 Island Press



Thickets of Chinese guava (*Psidium cattleianum*)  
Black River Gorges National Park, Mauritius  
photo P. Gonzalez





# Biome shifts alter specific habitats required by wildlife

Rathore et al. 2012 PLoS One

Tiger (*Panthera tigris*)  
Kanha National Park, India  
photo P. Gonzalez





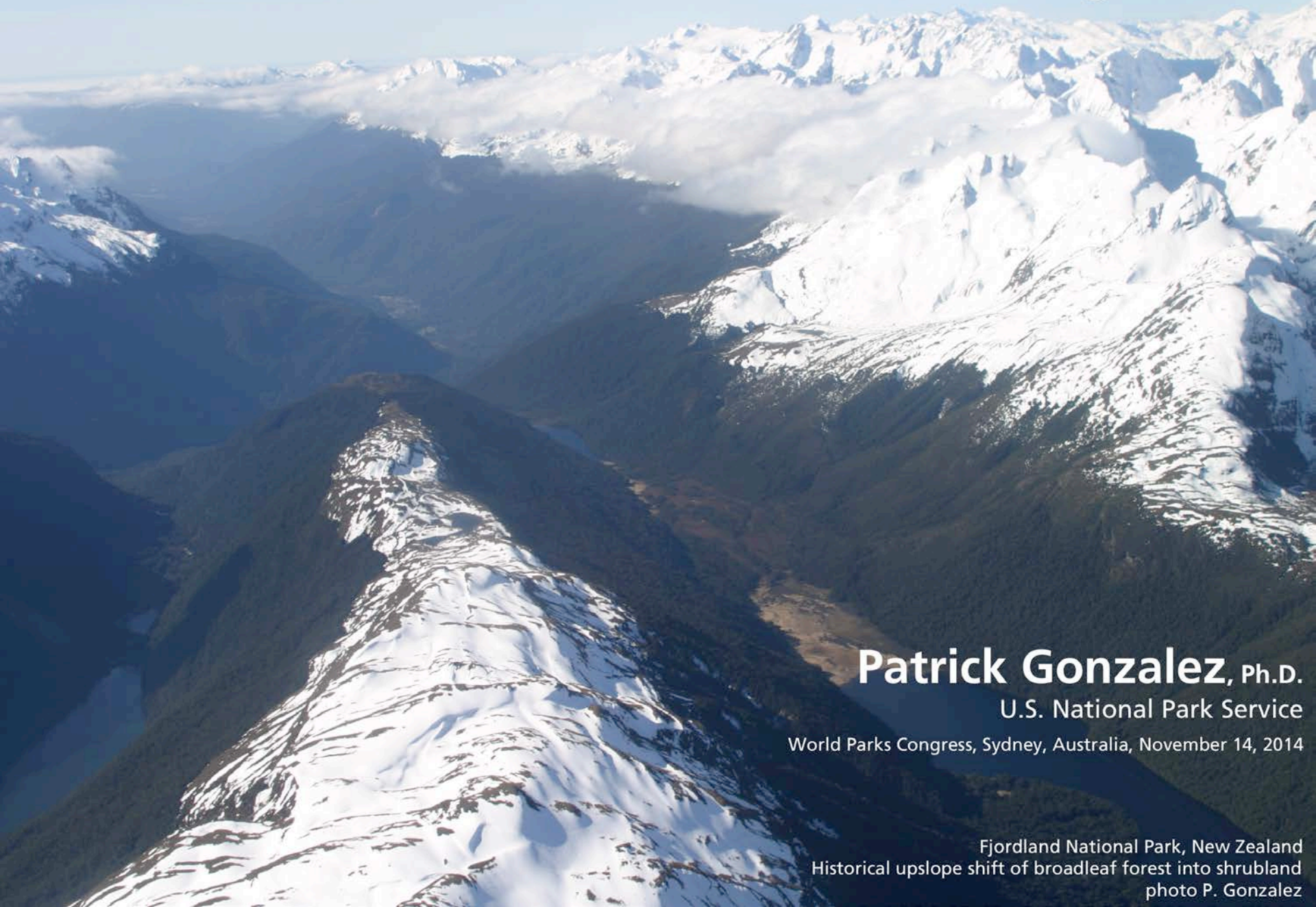
# Potential refugia and areas of high vulnerability to biome shifts offer priorities for new protection

Gonzalez 2011 Issues in Science and Technology

Coast Redwood (*Sequoia sempervirens*)  
Muir Woods National Monument, California USA  
photo P. Gonzalez



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