United States Department of Agriculture – Forest Service
Rocky Mountain Research Station

Highlights of the RMRS Climate Change Research FY2008

Highlights for 2008

- RMRS scientists collaborated to develop the RMRS Climate Change Strategic Plan (contact Brian Kent)

- RMRS scientists were lead authors on two highly influential Climate Change Science Program reports: SAP 4.3 and SAP 4.4. (contact Michael Ryan, Linda Joyce)

- Working with USFWS, RMRS scientists organized the symposium "Bull trout and climate change: risks, uncertainties, and opportunities for mapping the future" at the Western Division American Fisheries Society meeting (5/2008), providing an overview from leading experts across the Pacific Northwest of the current science pertaining to climate, potential impacts to stream habitats, and bull trout biology. Talks are available on the web (contact Dan Isaak).

- Working with NFS and State Agencies in Wyoming, RMRS organized the first climate change workshop on natural resource management in Wyoming: 6/16/08. Talks are available on the web (contact Linda Joyce)

- RMRS received 5 grants from the FS National Global Change Research Program:
  - Development and Delivery of a Climate-Driven Forest Vegetation Simulator, Nick Crookston
  - Designing wildlife corridors for a changing climate – Paul Beier, Curt Flather, Jeff Jenness
  - Climate-Change Toolkit for Western Forest Service Managers and Decision-Makers; Incorporating Climate into Everyday Resource Management; Neilson, Peterson, Millar, Joyce (PSW, PNW, and RMRS).
  - Tools to Assess and Assist Vulnerable Species At Risk From Climate Change, Deborah Finch
  - Forests and Carbon Storage – A Synthesis of the Science for Policymakers. Michael G. Ryan

- At the 8th National Conference on Science, Policy and the Environment, RMRS and PSW scientists led a breakout session on Forest Management and Climate Change, as part of the Climate Change: Science and Solutions, 8th National Conference on Science, Policy, and the Environment. Washington, DC. 1/17/2008 (contact Linda Joyce).

- RMRS and the Western Wildlands Environmental Threat Assessment Center organized a 2 day workshop entitled Vegetation Models and Climate Change for practioners (contact Linda Joyce).

- RMRS scientists organized a special symposium entitled "Potential impacts of climate change on diseases in natural ecosystems: Using history to predict the future" and gave talks at the Centennial annual meeting of the American Phytopathological Society, 26-30 July 2008, Minneapolis, MN (7/27/2008) (Contact: Ned Klopfenstein)

- RMRS scientists contributed to the draft USDA Strategy for Climate Change Research Extension, and Education (contact, Linda Joyce, Mike Ryan)

- RMRS scientists gave talks at National Forest Service meetings on topics of climate change, adaptation and mitigation: Region 1 Discussion Group on Climate Change (3/7/2008), Region 2 Renewable Resources Climate Change Workshop (2/26/2008, talks available on the web), Region 2 Climate Awareness Day (5/20/2008), family meetings on the Pike San Isabel NF and the Pikes Peak District, Region 3 Business Managers (3/1-2/2008), the national meeting of the USFS Public Affairs Officers (3/4/2008),

- RMRS scientists contributed information on the Climate Change Resource Center (www.fs.fed.us/ccrc)

- RMRS scientists have produced review papers on climate change and the Great Basin, western rangelands, forest diseases, stewardship of protected areas

- RMRS scientists have also produced numerous publications on carbon accounting, carbon allocation, and carbon dynamics in forests.

Highlights for 2009

- The "NM Forestry and Climate Change Workshop" held November 20, 2008 was organized by the Forest Guild and co-sponsored by the RMRS and the Biophilian Foundation, Thaw Charitable Trust, New Mexico Forest and Watershed Restoration Institute, the Bureau of Land Management New Mexico, and Los Alamos National Laboratory Foundation. This workshop provided foresters and other natural resource professionals up-to-date information on climate change and forests in New Mexico, including on-going research at RMRS; presentations available at www.forestguild.org/nmfccworkshop.html. (contact Deborah Finch)

- The RMRS and Region 1 Climate Change Partnership has the objectives of building on and expand the on-going public, stakeholder, and employee collaboration to address climate change in resource management and planning, and providing technology transfer and help understanding and sorting through the scientific literature. Towards that end a series of Climate Change Science Days have been and are planned in FY2009. These science days bring together experts in climate change and natural resource management. Activities include: 1) Kootenai National Forest, October 14, attendees included 40 employees, and an evening session with public; 2) Idaho Panhandle National Forest, October 15 – combined employee and stakeholders – 120 attendees, 3) Dakota Prairie Grasslands, December 5 – 50 employees – no public session, 4) Custer National Forest, December 12 – 20 employees and one reporter, 5) Lewis and Clark and Helena National Forests, late spring 2009. Before each Science Day, a sample of employees were interviewed in advance to determine topics of discussion and depth of presentations for the Science Day (contact: Cindy Swanson)

- ❖ RMRS scientists have synthesized key information from SAP 4.4 Report "Adaptation Options for Climate-Sensitive Ecosystems" in a 2 page format designed to be accessible to resource managers. Ten topics identified: 1) National Forest Management Options in Response to Climate Change, 2) Effects of Climate Change on National Forest Strategic Goals, 3) Adaptation Options in National Forests: Three Case Studies, 4) Adaptation Options for Watershed Management, 5) Adaptation Options for Invasive Species Management, 6) Adaptation Options for Wildlife Management, 7) Adaptation Options for Wildfire Management, 8) Adaptation Options for NFS Management and Human Dimensions, 9) Tools for Adaptation to Climate change, 10) Monitoring for Adaptation to Climate Change. Publication date Spring 2009 (contact Linda Joyce)

- ❖ Working with National Park Service and USGS staff, RMRS organized a ½ day session on Adaptation in the NPS Workshop 'Climate Change in the Crown of the continent: Identifying multi-jurisdictional Strategies, December 1-3, 2008. Attendees to the workshop included National Park Service, NFS staff, tribal groups, state agency staffs and NGOS. (contact Linda Joyce)

- ❖ By invitation, Karen Bagne and Deborah Finch are hosting a "Climate Change: Consequences for Birds" Symposium at the 2009 annual meeting of the Cooper Ornithological Society, April 18, 2009 (http://www.birdmeetings.org/cos2009/symposia.htm). (contact Deborah Finch)

2008 Review Publications

Bentz, B.J., C.D. Allen, M. Ayres, E. Berg, A. Carroll, M. Hansen, J. Hicke, L. Joyce, J. Logan, W. MacFarlane, J. MacMahon, S. Munson, J. Negron, T. Paine, J. Powell, K. Raffa, J. Régnière, M. Reid, W. Romme, S. Seybold, D. Six, D. Tomback, J. Vandygriff, T. Veblen, M. White, J. Witcosky, and D. Wood. In Press. Bark Beetle Outbreaks in Western North America: Causes and Consequences. University of Utah Press.

Bentz, B.J., C. J. Fettig, E. M. Hansen, J. Hicke, J. L. Hayes, R. Kelsey, J. Lundquist, J. Negrón, R. Progar, J. Régnière, S. Seybold, and J. Vandygriff. 2008. Climate Change and Western Bark Beetles: Rapid Threat Assessment. Currently at www.fs.fed.us/wwetac/projects/PDFs/RTA_Bark_Beetle.pdf;

Chambers, JC. 2008. Climate Change and the Great Basin. General Technical Report. RMRS-GTR-204: In J. C. Chambers, A. Evenden and N. Devoe, compilers. Collaborative management and research in the Great Basin – Examining the issues and developing a framework for moving forward. USDA Forest Service, Rocky Mountain Research Station.

Chambers, J. C. and M. Pellant. 2008. Climate Change Impacts on Northwestern and Intermountain US Rangelands. Rangelands 30:29-33.

Cole, D.N., L.Yung, E.S. Zavaleta, G. H. Aplet, F. S. Chapin III, D. M. Graber, E. S. Higgs, R. J. Hobbs, P. B. Landres, C. I.Millar, D. J. Parsons, J. M. Randall, N. L. Stephenson, K. A. Tonnessen, P. S. White, and S. Woodley. Naturalness and beyond: protected area stewardship in an era of global environmental change. The George Wright Forum 25: 36-56.

Kliejunas, J. T.; Geils, B.; Glaeser, J. M.; Goheen, E. M.; Hennon, P.; Kim, M-S.; Kope, H.; Stone, J.; Sturrock, R. and Frankel, S.J. Climate and Forest Diseases of Western North America: A Literature Review. September 24, 2008. General Technical Report. PSW-GTR-XXX. USDA Forest Service, Pacific Southwest Research Station, Albany. 36 p. [Online]. http://www.fs.fed.us/psw/topics/climate_change/forest_disease/Final.Forpathandcc.lit.jk.2008.09.24.pdf

Wildlife

Rieman, B.E., D.J. Isaak, S. Adams, D. Horan, D. Nagel, C. Luce, D. Myers, 2007. Anticipated effects of climate warming on bull trout within the Interior Columbia River Basin. Transactions of the American Fisheries Society. 136: 1552-1565.

Insects

Raffa, K.F, B. H. Aukema, B. J. Bentz, A. L. Carroll, J. A. Hicke, M. G. Turner, W. H. Romme. 2008. Cross-scale Drivers of Natural Disturbances Prone to Anthropogenic Amplification: Dynamics of Biome-wide Bark Beetle Eruptions. BioScience 58(6):501-518.

Brunelle, A., G. Rehfeldt, B. Bentz and S. Munson. 2008. Holocene records of Dendroctonus bark beetles in high elevation pine forests of Idaho and Montana, USA. Forest Ecology and Management 255:836-846.

Clifford, M.J., M.E. Rocca, R. Delph, P.L. Ford, and N.S. Cobb. September 2008. Drought Induced Tree Mortality and Ensuing Bark Beetle Outbreaks in Southwestern Pinyon-Juniper Woodlands. In: Gottfried, Gerald J.; Shaw, John D.; Ford, Paulette L., compilers. 2008. Ecology, management, and restoration of piñon-juniper and ponderosa pine ecosystems: proceedings of the 2005 St. George, Utah and 2006 Albuquerque, New Mexico workshops. Proceedings RMRS-P-51. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Pp. 39.

Fire

Heyerdahl, E.K., P. Morgan, and J.P. Riser II. 2008. "Multi-season climate synchronized historical fires in dry forests (1650-1900), northern Rockies, USA" Ecology. 89:705-716.

Morgan, P., E.K. Heyerdahl, and C.E. Gibson. 2008. "Multi-season climate synchronized forest fires throughout the 20th century, northern Rockies, USA" Ecology. 89:717-728.

Keane, R. E., L. Holsinger, R. Parsons, and Gray, Kathy. 2008. Climate change effects on historical range of variability of two large landscapes in western Montana, USA. Forest Ecology and Management 254:274-289.

Ford, P. L. 2008. Effects of 10 years of fire and climate variability on perennial grass cover in shortgrass steppe. In: Multifunctional grasslands in a changing world: proceedings XXI International Grassland Congress and VIII International Rangeland Congress, Hohhot, Inner Mongolia Autonomous Region, People's Republic of China, June 23 to July 13, 2008. Guangdong People's Publishing House. Edited by Organizing Committee of 2008 IGC/IRC Conference. Pp. 75.

Carbon

Cavaleri MA, Oberbauer SF and MG Ryan. 2008. Foliar and ecosystem respiration in an old-growth tropical rain forest. 2008. Plant Cell & Environment 31: 473-483.

Clark DB, PC Olivas, SF Oberbauer, DA Clark and MG Ryan. 2008. First direct landscape-scale measurement of tropical rain forest Leaf Area Index, a key driver of global primary productivity. Ecology Letters 11: 163-172.

Sherrill KR, MA Lefsky, JB Bradford, and MG Ryan. 2008. Forest Structure Estimation and Pattern Exploration from Discrete Return Lidar in Subalpine Forests of the Central Rockies. Canadian Journal of Forest Research 38:2081–2096.

Litton CM, JW Raich and MG Ryan. 2007. Carbon allocation in forest ecosystems (review article). Global Change Biology 13: 2089-2109.

Bradford JB, P Weishampel, M-L Smith, RK Kolka, DY Hollinger, RA Birdsey, S Ollinger and MG Ryan. 2008. Landscape-Scale Carbon Sampling Strategy – Lessons Learned. Pages 227-238 in CM Hoover, editor, Field measurements for forest carbon monitoring: A landscape-scale approach, Springer, New York, NY, USA.

Bradford JB and MG Ryan. 2008. Quantifying soil respiration at landscape-scales. Pages 143-162 in CM Hoover, editor, Field measurements for forest carbon monitoring: A landscape-scale approach, Springer, New York, NY, USA.

Assessment of Climate Change

Joyce, LA. 2007. Climate Change Impacts on Forestry. Chapter 14. In: DM Adams and RW Haynes. Resource and Market Projections for Forest Development: Twenty Five years' Experience with the US RPA Timber Assessment. Dordrecht, The Netherlands: Springer: 451-490.

Bosworth, Dale, Birdsey, Richard, Joyce, Linda, Millar, Constance. 2008. Climate Change and the Nation's Forests: Challenges and Opportunities. Journal of Forestry June 2008, pages 214-221.

Joyce, LA.2008. Forestry, Ecosystems, and Wildlife. IN: Ozzello, Lori (ed.), Citizens' Guide to Colorado Climate Change. Colorado Foundation for Water Education, Denver, Colorado: pages 36-38

US Climate Change Science Program Synthesis and Assessment Reports

CCSP, 2008: Preliminary review of adaptation options for climate-sensitive ecosystems and resources. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Julius, SH, JM West (eds.), JS Baron, B Griffith, LA Joyce, P Kareiva, BD Keller, MA Palmer, CH Peterson, and JM Scott (Authors)]. U.S. Environmental Protection Agency, Washington, DC, USA, 873 pp.

CCSP, 2008: The effects of climate change on agriculture, land resources, water resources, and biodiversity. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. P Backlund, A Janetos, D Schimel, J Hatfield, K Boote, P Fay, L Hahn, C Izaurralde, BA Kimball, T Mader, J Morgan, D Ort, W Polley, A Thomson, D Wolfe, MG Ryan, SR Archer, RA Birdsey, CN Dahm, LS Heath, JA Hicke, DY Hollinger, TE Huxman, GS Okin, R Oren, JT Randerson, WH Schlesinger, D Lettenmaier, D Major, L Poff, S Running, L Hansen, D Inouye, BP Kelly, L Meyerson, B Peterson, R Shaw. US Environmental Protection Agency, Washington, DC, USA, 362 pp.

Joyce, LA, Blate, G, Littell, J, McNulty S, Millar, C, Moser S, Neilson R, O'Halloran, K, Peterson DL. 2008. National Forests. IN: Julius, SH, JM West, JS Baron, B Griffith, LA Joyce, P Kareiva, BD Keller, MA Palmer, CH Peterson, and JM Scott (Authors). Preliminary Review of Adaptation options for Climate-Sensitive Ecosystems and Resources. Synthesis and Assessment Product 4.4. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. U.S. Environmental Protection Agency, Washington, DC, USA, 3-1 to 3-127 pp.

Ryan MG, SR Archer, RA Birdsey, CN Dahm, LS Heath, JA Hicke, DY Hollinger, TE Huxman, GS Okin, R Oren, JT Randerson, WH Schlesinger, 2008. Land Resources. In: The effects of climate change on agriculture, land resources, water resources, and biodiversity. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington, DC, USA, 362 pp.

Climate Change Resource Center publications (http://fs.fed.us/ccrc)

Joyce, LA. 2008. Climate Change Assessments. (web published May 20, 2008). U.S. Department of Agriculture, Forest Service, Climate Change Resource Center. http://www.fs.fed.us/ccrc/topics/assessments

Ryan, MG. 2008. Forests and Carbon Storage. (June 04, 2008). U.S. Department of Agriculture, Forest Service, Climate Change Resource Center.

Appendix – Additional Details

Highights on 2008 Publications Related to Climate Change

US Climate Change Science Program Publications

The U.S. Climate Change Science Program recently published two synthesis and assessment products that are very relevant to management of National Forests and Grasslands, address the Government Accountability Office 2007 recommendation that agencies develop guidance for addressing the effects of climate change on Federal land and water resources, and where Forest Service Scientists served a critical role in developing the assessments:

CCSP, 2008: The effects of climate change on agriculture, land resources, water resources, and biodiversity. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. P Backlund, A Janetos, D Schimel, J Hatfield, K Boote, P Fay, L Hahn, C Izaurralde, BA Kimball, T Mader, J Morgan, D Ort, W Polley, A Thomson, D Wolfe, MG Ryan, SR Archer, RA Birdsey, CN Dahm, LS Heath, JA Hicke, DY Hollinger, TE Huxman, GS Okin, R Oren, JT Randerson, WH Schlesinger, D Lettenmaier, D Major, L Poff, S Running, L Hansen, D Inouye, BP Kelly, L Meyerson, B Peterson, R Shaw. US Environmental Protection Agency, Washington, DC, USA, 362 pp.

CCSP, 2008: Preliminary review of adaptation options for climate-sensitive ecosystems and resources. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Julius, SH, JM West (eds.), JS Baron, B Griffith, LA Joyce, P Kareiva, BD Keller, MA Palmer, CH Peterson, and JM Scott (Authors)]. U.S. Environmental Protection Agency, Washington, DC, USA, 873 pp.

The two chapters most relevant to the Forest Service (SAP 4.3 'Land Resources' and SAP 4.4 'National Forests') provide several new resources for natural resource managers. First, they are an excellent primer on how climate change will impact forest and arid land ecosystems and how the impacts will differ in different regions of the country. Second, they provide an up-to-date synthesis of the literature on climate change impacts and adaptation. Third, these chapters highlight the role of climate change and disturbance (fire, insect outbreaks, storms) and discuss the challenges for management and also the opportunity for different management after disturbance. Fourth, the 'National Forests' chapter worked with National Forest managers to see how incorporating climate change into management plans might work. These case studies taught both managers and scientists many lessons, and led to an ongoing effort to expand the research-management collaboration to incorporate climate change into forest management. Finally, the chapter summary 'finding' are valuable signposts for managers planning for the next 30-50 years.

Comparing the pollution generated by different forest residues treatment

Study results show that utilizing forest treatment residues for energy production in a biomass boiler substantially reduces greenhouse gas and particulate matter emissions compared to pile burning these residues on site and using fossil fuels to obtain the equivalent amount of energy in a boiler. Diesel consumption required to collect, grind, and haul this forest residue biomass represents only about 5% of the total emissions of the bioenergy alternative and is little effected by haul distances up to 85 miles. This means that there may be an opportunity to trade carbon credits for utilizing forest biomass for energy production, which in turn could provide an additional source of funding for accomplishing work through the use of stewardship contracting. Also, utilizing this material for energy reduces smoke production compared to pile burning,

which may be important for accomplishing fuel reduction and/or forest restoration work in locations where air quality is an issue. Who was involved in the Accomplishment: Human Dimensions Science Program (Greg Jones, Janet Sullivan, Kurt Krueger, Dave Calkin), Univ of Montana, College of Forestry and Conservation (Dan Loeffler, Edward Butler.

Report (Jones, Greg; Loeffler, Dan. 2007. What pollutes more: burning logging scraps on-site or hauling them to boilers? Missoula, MT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Forestry Sciences Laboratory. p. 9,14.)

Interactions of Forest Plant Pathogens and Weather and Climate

The Pacific Southwest Research Station with scientific support from the Rocky Mountain Research Station (Geils and Kim, Forest and Woodland Ecosystems Program) and other agencies have prepared a literature review and database on the interactions of forest plant pathogens with weather and climate. Forest plant diseases are heavily influenced by weather and climate. For forest pathogenic fungi, bacteria, viruses and other microorganisms, the temperature and moisture conditions interacting with the host determine infection severity and disease distribution. Extreme weather, i.e. drought or typhoons, can kill large expanses of trees directly by overwhelming tree physiological and structural strength. Patterns and rates of wood decay, caused by forest fungi, are also expected to change in response to climate changes which will influence forest carbon cycles. Expected changes in climate coupled with the increasing stresses of invasive species, lack of fire, and forest fragmentation are creating conducive conditions for many forest plant diseases. Results from a review of the literature support the position that forest disease is an important process by which weather and climate have an indirect effect on forest ecosystems. These interactions, however, are sufficiently complex that disease epidemics and effects should be anticipated but may not be specifically predictable and responsive to traditional management. Promising alternatives include adaptive management (36 CFR 219.16; FSM 1905) for resilience (FSM 2000, Chapter 2020).

Kliejunas, J. T.; Geils, B.; Glaeser, J. M.; Goheen, E. M.; Hennon, P.; Kim, M-S.; Kope, H.; Stone, J.; Sturrock, R. and Frankel, S.J. Climate and Forest Diseases of Western North America: A Literature Review. September 24, 2008. General Technical Report. PSW-GTR-XXX. USDA Forest Service, Pacific Southwest Research Station, Albany. 36 p. [Online].
http://www.fs.fed.us/psw/topics/climate_change/forest_disease/Final.Forpathandcc.lit.jk.2008.09.24.pdf

Climate Change Affecting Distribution of Bull Trout

Bull trout , Salvelinus confluentus, are dependent on cold water. They are also listed as a threatened species under the Endangered Species Act. Conservation of these fish under a warming climate requires an understanding of how their distribution is changing. We modeled the relationships between (1) the lower elevation limits of small bull trout and mean annual air temperature and (2) latitude and longitude across the species' potential range within the interior Columbia River basin of the USA. We used our results to explore the implications of the climate warming expected in the next 50 or more years. We found a strong association between the lower elevation limits of bull trout distributions and longitude and latitude; this association was consistent with the patterns in mean annual air temperature. We concluded that climate does strongly influence regional and local bull trout distributions, and we estimated bull trout habitat response to a range of predicted climate warming effects. Warming over the range predicted

could result in losses of 18–92% of thermally suitable natal habitat area and 27–99% of large (.10,000-ha) habitat patches, which suggests that population impacts may be disproportionate to the simple loss of habitat area. The predicted changes were not uniform across the species' range, and some populations appear to face higher risks than others. These results could provide a foundation for regional prioritization in conservation management, although more detailed models are needed to prioritize actions at local scales.

Rieman, B.E., D.J. Isaak, S. Adams, D. Horan, D. Nagel, C. Luce, D. Myers, 2007. Anticipated effects of climate warming on bull trout within the Interior Columbia River Basin. Transactions of the American Fisheries Society. 136: 1552-1565.

Causes and Consequences of Bark Beetle Outbreaks in Western North America

A panel of experts was convened to discuss the causes and consequences of recent widespread bark beetle outbreaks in western North America. Climate change, in addition to other factors, was identified as a significant influencing factor in population outbreak dynamics. A non-technical summary of the information discussed at the workshop was developed to inform land managers and the general public about the issue.

Bentz, B.J., C.D. Allen, M. Ayres, E. Berg, A. Carroll, M. Hansen, J. Hicke, L. Joyce, J. Logan, W. MacFarlane, J. MacMahon, S. Munson, J. Negron, T. Paine, J. Powell, K. Raffa, J. Régnière, M. Reid, W. Romme, S. Seybold, D. Six, D. Tomback, J. Vandygriff, T. Veblen, M. White, J. Witcosky, and D. Wood. In Press. Bark Beetle Outbreaks in Western North America: Causes and Consequences. University of Utah Press.

The human influences on the dynamics of bark beetle epidemics

Bark beetle outbreaks are a result of a complex system of cross-scale feedbacks. A description of ecosystem components and the feedbacks involved was developed to inform the scientific community and land managers of the intricacies involved in bark beetle outbreak dynamics and how climate change influences the interactions.

Raffa, K.F, B. H. Aukema, B. J. Bentz, A. L. Carroll, J. A. Hicke, M. G. Turner, W. H. Romme. 2008. Cross-scale Drivers of Natural Disturbances Prone to Anthropogenic Amplification: Dynamics of Biome-wide Bark Beetle Eruptions. BioScience 58(6):501-518.

The Paleo-record and bark beetle outbreaks.

Knowledge of forest disturbance history is an important aspect of forest management. Historical records of disturbances, such as bark beetle outbreaks, are often limited to the time frame available based on tree rings or written records. Evidence of Dendroctonus beetle fossils in high elevation lake sediments were used to evaluate the relationship between climate, fire, and bark beetles in records dating back to the Holocene. This information is important for establishing baseline data on the role of bark beetle outbreaks in high elevation forests and the role of climate change.

Brunelle, A., G. Rehfeldt, B. Bentz and S. Munson. 2008. Holocene records of Dendroctonus bark beetles in high elevation pine forests of Idaho and Montana, USA. Forest Ecology and Management 255:836-846.

Understanding Past Climate Drivers Of Fire Allows Planning For Climate Change

Widespread fires, like those in 1910, 2000 and 2003, can quickly overwhelm our ability to control them. Such regional-fire years can reset forest succession over large areas and result in more extensive fires in the future. The cumulative effect of these extensive fires could alter regional forest carbon budgets, water and nutrient cycles, and habitats of species of conservation concern. Understanding the climate conditions under which regional-fire years occurred in the past is critical to predicting the effects of climatic variability and climatic change on future fire extent and severity.

Emily Heyerdahl at our Fire Sciences Laboratory in Missoula, Montana in collaboration with Penny Morgan from the University of Idaho, identified the climate conditions under which regional-fire years have occurred over the past three and a half centuries in the Northern Rockies. They used both tree rings and written records to show to that regional-fire years were ones when warm springs were followed by warm, dry summers. Furthermore, 20th century regional-fire years were also influenced by the Pacific Decadal Oscillation, when spring snowpack was low and hence fire seasons longer. Climate continues to be a major driver of regional-fire years in this region despite intensive fire suppression, logging, and domestic livestock grazing.

Heyerdahl, E.K., P. Morgan, and J.P. Riser II. 2008. "Multi-season climate synchronized historical fires in dry forests (1650-1900), northern Rockies, USA" Ecology. 89:705-716.

Morgan, P., E.K. Heyerdahl, and C.E. Gibson. 2008. "Multi-season climate synchronized forest fires throughout the 20th century, northern Rockies, USA" Ecology. 89:717-728.

Incorporating climate change predictions into landscape planning

This paper presented a simplified approach for management to include climate change predictions into their landscape planning.

Keane, R. E., L. Holsinger, R. Parsons, and Gray, Kathy. 2008. Climate change effects on historical range of variability of two large landscapes in western Montana, USA. Forest Ecology and Management 254:274-289.

Climate Change and New Mexico

Hall, S. A., and R. D. Periman. 2007. Unusual Holocene alluvial record from Rio Del Oso, Jemez Mountains, New Mexico: paleoclimatic and archaeologic significance. New Mexico Geological Society, 58th Field Conference, Guidebook, 459-468 (EMU)

Climate Change and the Great Basin.

This publication examines climate change predictions specific to the Great Basin, outlines management issues associated with climate change, and lists critical research and management questions. It also provides information on national and regional organizations who currently are addressing climate change issues relevant to the Great Basin.

General Technical Report. RMRS-GTR-204: Chambers, J. C. 2008. Climate Change and the Great Basin. In J. C. Chambers, A. Evenden and N. Devoe, compilers. Collaborative management and research in the Great Basin – Examining the issues and developing a framework for moving forward. USDA Forest Service, Rocky Mountain Research Station.

Climate change and northwestern and Intermountain US Rangelands

This publication focuses on two western regions and explores the climate change implications from a rangeland science and managment perspective. It discusses climate change

predictions for the region, and examines likely outcomes with regard to water resources, species and ecosystems, biodiversity, exotic species invasions and altered fire regimes. It concludes with a discussion of managment and policy implications.

Rangelands 30:29-33. Chambers, J. C. and M. Pellant. 2008. Climate Change Impacts on Northwestern and Intermountain US Rangelands.

Climate Change and the Stewardship of Protected Areas

The Aldo Leopold Wilderness Research Institute recently held workshops to explore the implications of global change for the stewardship of protected areas, particularly wilderness and national parks. This synthesis paper is relevant to Forest Service wilderness managers and other managers of protected areas. The traditional goals that have guided the conservation and restoration of large protected areas—most notably naturalness—no longer provide sufficient guidance to make good decisions about intervening in ecosystem processes, given climate change and the multiple stressors that all protected areas face. The paper outlines ways to better articulate and develop new stewardship goals, as well as some potential strategies that might be employed to achieve those goals.

Cole, D.N., L.Yung, E.S. Zavaleta, G. H. Aplet, F. S. Chapin III, D. M. Graber, E. S. Higgs, R. J. Hobbs, P. B. Landres, C. I.Millar, D. J. Parsons, J. M. Randall, N. L. Stephenson, K. A. Tonnessen, P. S. White, and S. Woodley. Naturalness and beyond: protected area stewardship in an era of global environmental change. The George Wright Forum 25: 36-56.

Carbon and Tropical Forests

Tropical forests store > 60% of the carbon of terrestrial ecosystems and they are vulnerable to loss through deforestation and potential changes in physiology in response to a warmer climate. This study examined a little-studied component of the ecosystem carbon balance and found that foliar and wood respiration varied within the canopy with the highest rates near the canopy top. Ecosystem respiration estimated by chambers was 30% greater than that estimated by eddy covariance, suggesting that eddy covariance estimates of ecosystem carbon storage are substantially high.

Cavaleri MA, Oberbauer SF and MG Ryan. 2008. Foliar and ecosystem respiration in an old-growth tropical rain forest. 2008. Plant Cell & Environment 31: 473-483.

Tropical forests store > 60% of the carbon of terrestrial ecosystems and they are vulnerable to loss through deforestation and potential changes in physiology in response to a warmer climate. Leaf area is a key indicator of ecosystem physiology and carbon uptake, but because of the diversity of tree species, it has never been directly measured for a wet tropical forest. We used an innovative vertical quadrat sampling technique to sample leaf area in a primary tropical forest. Leaf area on the scale of our sample (~4 m2) was remarkably consistant with a coefficient of variance of only 35%. Up to 20 m, canopy height was an excellent predictor of leaf area—above that, leaf area and height were not correlated.

Clark DB, PC Olivas, SF Oberbauer, DA Clark and MG Ryan. 2008. First direct landscape-scale measurement of tropical rain forest Leaf Area Index, a key driver of global primary productivity. Ecology Letters 11: 163-172.

Estimating Carbon with Small Footprint Lidar

This study showed that small footprint lidar is very good at estimating carbon pools and fluxes for a range of subalpine forest ecosystem. Lidar estimates were exceptionally good for carbon in aboveground biomass, but also reasonably good for the carbon in dead wood, forest floor, and soil—which were themselves unrelated to aboveground characheristics.

Sherrill KR, MA Lefsky, JB Bradford, and MG Ryan. 2008. Forest Structure Estimation and Pattern Exploration from Discrete Return Lidar in Subalpine Forests of the Central Rockies. Canadian Journal of Forest Research 38:2081–2096.

A Review of the Carbon Balance Approach to estimating Carbon allocation

Carbon allocation (the use of photosynthesis for metabolism and growth of leaves, wood, and roots) is one of the big unsolved problems preventing a mechanistic understanding of tree and forest growth. One of the reasons that carbon allocation has been seen as a tough problem is that studies rarely measure all of the components, particularly photosynthesis used belowground and for respiration. This paper is a synthesis of studies that used a carbon balance approach to study of carbon allocation. We propose terminology to help clear confusion about different aspects of carbon allocation, and tests several hypotheses. The data show that annual fluxes to roots, leaves and wood are unrelated to standing biomass, that increased photosynthesis increases annual flux to all components, and that annual flux to leaf production and respiration is a constant proportion of photosynthesis. Increased resources increase the fraction of photosynthesis used for wood production and decrease the fraction of photosynthesis used belowground.

Litton CM, JW Raich and MG Ryan. 2007. Carbon allocation in forest ecosystems (review article). Global Change Biology 13: 2089-2109.

Landscape-scale carbon sampling strategy

Within a book on sampling carbon at larger scales, this publication shows that the FIA plot design is inefficient for sampling at the landscape scale and that the 4 ‘subplots’ would be better distributed as independent plots. Sampling effort should the size of the carbon pool or flux and its variability. Fluxes were substantially more difficult to estimate than pools: measurements cost substantially more and were more variable.

Bradford JB, P Weishampel, M-L Smith, RK Kolka, DY Hollinger, RA Birdsey, S Ollinger and MG Ryan. 2008. Landscape-Scale Carbon Sampling Strategy – Lessons Learned. Pages 227-238 in CM Hoover, editor, Field measurements for forest carbon monitoring: A landscape-scale approach, Springer, New York, NY, USA.

Within a book on sampling carbon at larger scales, this publication suggests methodology for quantifying soil respiration at larger scales.

Bradford JB and MG Ryan. 2008. Quantifying soil respiration at landscape-scales. Pages 143-162 in CM Hoover, editor, Field measurements for forest carbon monitoring: A landscape-scale approach, Springer, New York, NY, USA.

Climate Change and Grasslands

Ford, P. L. 2008. Effects of 10 years of fire and climate variability on perennial grass cover in shortgrass steppe. In: Multifunctional grasslands in a changing world: proceedings XXI International Grassland Congress and VIII International Rangeland Congress, Hohhot, Inner Mongolia Autonomous Region, People's Republic of China, June 23 to July 13, 2008. Guangdong People’s Publishing House. Edited by Organizing Committee of 2008 IGC/IRC Conference. Pp. 75.

Clifford, M.J., M.E. Rocca, R. Delph, P.L. Ford, and N.S. Cobb. September 2008. Drought Induced Tree Mortality and Ensuing Bark Beetle Outbreaks in Southwestern Pinyon-Juniper Woodlands. In: Gottfried, Gerald J.; Shaw, John D.; Ford, Paulette L., compilers. 2008. Ecology, management, and restoration of piñon-juniper and ponderosa pine ecosystems: proceedings of the 2005 St. George, Utah and 2006 Albuquerque, New Mexico workshops. Proceedings RMRS-P-51. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Pp. 39.

Hall, S. A., and R. D. Periman. 2007. Unusual Holocene alluvial record from Rio Del Oso, Jemez Mountains, New Mexico: paleoclimatic and archaeologic significance. New Mexico Geological Society, 58th Field Conference, Guidebook, 459-468 (EMU)

Web-based publications

A primer on forests and carbon storage.

Ryan, MG. 2008. Forests and Carbon Storage. (June 04, 2008). U.S. Department of Agriculture, Forest Service, Climate Change Resource Center.

Joyce, LA. 2008. Climate Change Assessments. (web published May 20, 2008). U.S. Department of Agriculture, Forest Service, Climate Change Resource Center. http://www.fs.fed.us/ccrc/topics/assessments

Education

Bull trout and climate change

RMRS postdoctoral researcher Dan Isaak and USGS aquatic ecologist Jason Dunham (formerly with RMRS) organized a symposium entitled "Bull trout and climate change: risks, uncertainties, and opportunities for mapping the future" at the Western Division American Fisheries Society meeting in May of 2008. The symposium was coordinated with the USFWS, which is the lead agency in bull trout recovery efforts, and provided an overview from leading experts across the Pacific Northwest of the current science pertaining to climate, potential impacts to stream habitats, and bull trout biology. participated in the session. Speaker presentations were recorded and are available online. Specific topics included: case histories of bull trout and climate, observed and projected climate trends for the PNW, key habitat requirements for bull trout, modeling impacts of climate change on stream temperatures, hydrology, and fluvial geomorphology.

A compilation of symposium presentations given at the 2008 Western Division American Fisheries Society meeting, Portland, OR, May 4 – 9. (www.fs.fed.us/rm/boise/AWAE/projects/bull_trout/bt_home.html).

Climate Change in Wyoming

The one-day workshop was designed to bring state and federal agencies together to learn more about the climate, resources that could be impacted, potential adaptation and carbon mitigration. The workshop concluded with a panel discussion by state and federal resource managers. Workshop was organized by Sharon Kyhl, USFS Wyoming, Linda Joyce, RMRS, and Terry Cleveland, State of Wyoming. June 16, 2008. Sponsored by Wyoming Department of Agriculture, Wyoming Game and Fish Department, Wyoming Department of Environmental Quality, Wyoming Travel and Tourism, Wyoming Office of State Lands and Investments, USFS, and USFS Rocky Mountain Research Station. Powerpoints are available on the web: http://gf.state.wy.us/climatechangeworkshop/index.asp

Contacts:

Barbara J. Bentz
USDA Forest Service
860 N. 1200 E. Logan, UT 84321
Phone : 435-755-3577 Fax : 435-755-3563 email: bbentz@fs.fed.us

Jeanne C. Chambers
USDA Forest Service Rocky Mountain Research Station
920 Valley Road, Reno NV 89512
Phone: 775-784-5329 Fax: 775-784-4583

David Cole
Aldo Leopold Wilderness Research Institute
fax: 406-542-4196 email: dcole@fs.fed.us

Deborah Finch
USDA Forest Service Rocky Mountain Research Station
333 Broadway SE, Suite 115
Albuquerque, NM 87102
voice 505-724-3671, cell 505-401-0580

BRIAN W. GEILS
USDA Forest Service, Rocky Mountain Research Station
Southwest Forest Science Complex
2500 South Pine Knoll Drive
Flagstaff, AZ 86001
Phone: (928) 556-2076, Email: bgeils@fs.fed.us

Wei Min Hao
US Forest Service RMRS Fire Sciences Laboratory
5775 US Highway 10 West
Missoula, MT 59808
T: (406) 329-4838, F: (406) 329-4863, email: whao@fs.fed.us

Emily K. Heyerdahl
USDA Forest Service Rocky Mountain Research Station
Fire Sciences Laboratory
5775 US W Highway 10
Missoula, MT 59808
406-829-6939, email: eheyerdahl@fs.fed.us

Dan Isaak
Rocky Mountain Research Station Boise Aquatic Sciences Lab
322 E. Front St., Suite 401
Boise, ID 83702
Phone: (208) 373-4385, Fax: (208) 373-4391

Greg Jones
Rocky Mountain Research Station Forestry Sciences Lab.
800 East Beckwith Ave.

Missoula, MT 59801
Phone: (406) 542-4167; Fax: (406) 543-2663, email: jgjones@fs.fed.us

Linda Joyce
USDA FS Rocky Mountain Research Station
240 West Prospect
Fort Collins, CO 80526
Phone: 970-498-2560, Email: ljoyce@fs.fed.us

Bob Keane
Rocky Mountain Research Station Missoula Fire Sciences Laboratory
5775 West US Hwy 10
Missoula, MT 59808-9361
Phone: 406-329-4846 FAX: 406-329-4877, Email: rkeane@fs.fed.us

NED B. KLOPFENSTEIN
USDA Forest Service, RMRS Forestry Sciences Laboratory
1221 South Main
Moscow, ID 83843 U.S.A.
ph: 208-883-2310, fax: 208-883-2318, email: nklopfenstein@fs.fed.us

Rachel Loehman
Rocky Mountain Research Station Fire Sciences Laboratory
5775 West US Hwy 10
Missoula, MT 59808-9361
Phone: 406-829-7386/Fax: 406-329-4877, Email: rloehman@fs.fed.us

Charlie Luce
USDA Forest Service
322 E. Front St., Suite 401
Boise, ID 83702
(208) 373-4382 Office, (208) 761-5017 Cell, email: cluce@fs.fed.us

Michael G. Ryan
USDA Forest Service RMRS
240 West Prospect Rd
Fort Collins, CO 80526
970.498.1012, email : mgryan@fs.fed.us

Cindy Swanson
USDA Forest Service, Rocky Mountain Research Station
Forestry Sciences Laboratory
800 East Beckwith Avenue
Missoula, MT 59801
406-542-4172; Fax: 406-543-2663; email: cswanson@fs.fed.us