Hope in an Era of Climate Change

Roadless Areas in National Forests

Dominick A. DellaSala,
Jim Furnish, and
Eric Steinkamp

January 2011

The Authors

Dominick DellaSala is President and Chief Scientist of the Geos Institute, based in Ashland, Oregon. Dr. DellaSala is also President of the North American Section of the Society for Conservation Biology. He holds a B.S. in Biology from Adelphi University, an M.S. in Ecology from Wayne State University, and a Ph.D. in Natural Resources from the University of Michigan. His expertise is in forest and fire ecology, endangered species management, and climate change science.

Jim Furnish is a consulting forester in the Washington, D.C., area. This follows a 34-year career with the USDA Forest Service where he served as Deputy Chief of the 192 million acre National Forest System and also worked in the Rocky Mountain Region. Mr. Furnish is an auditor for "green" certified forest lands and products under the Forest Stewardship Council label. He also is on the Board of Directors for both Wildlands CPR and the Evangelical Environmental Network.

Eric Steinkamp is Professor of Environmental Science and Math and Science Department Chair at Northwest University, based in Kirkland, Washington. Dr. Steinkamp holds a B.S. in Forestry from the University of Illinois, an M.S. in Forest Management from Stephen F. Austin State University, and a Ph.D. in Forest Science from Colorado State University. He also has a Master of Divinity from the Assemblies of God Theological Seminary. Dr. Steinkamp's interests include application of environmental technologies in developing countries, studying alpine ecosystems, and the interplay between Christian theological understanding and environmental stewardship.

The Editors

Suellen Lowry, Noah Alliance, Allied Voices.
Tom Turner, Earthjustice.

Cover photograph: Dave Powell/U.S. Forest Service

Nelson Guda

" 'Has not my hand made all these things, and so they came into being?' declares the LORD."
—Isaiah 66:2

Contents

"Our very contact with nature has a deep restorative power; contemplation of its magnificence imparts peace and serenity. The Bible speaks again and again of the goodness and beauty of creation, which is called to glorify God."

—Pope John Paul II, Jan. 1, 1990

Nelson Guda

Introduction

Creation Care and Climate Change

"The concept of himā (protection of certain zones) has existed since the time of the Prophet Muhammad. Himā involved the ruler or government's protection of specific unused areas. No one may build on them or develop them in any way."

—Mawil Y. Izzi Deen (Samarrai) "Islamic Environmental Ethics, Law, and Society"

Teachings from many religious traditions describe God's hand in creating our beautiful and life-sustaining planet. They also encourage us to treat the Earth with reverence, respect, and in a sustainable way. Moreover, people from all walks of life find spirit-nurturing sustenance in the wild, pristine parts of our world.

We have been entrusted with an awe-inspiring web of life; however, all is not well. The effects of climate change are becoming more visible each day, and as global and regional climates alter, both natural and human communities will face significant disruptions in many of nature's life-giving services. Efforts are under way to reverse this trend by reducing and eventually eliminating the use of fossil fuels, developing sustainable energy systems, reforming transportation, and modifying forestry and agricultural practices. All are vital.

Wild Forests Stem Climate Change and Some of Its Significant Effects

Meanwhile, one important but often underappreciated element of a comprehensive strategy to address climate change exists already—wild forests, also known as intact forests. This white paper sets forth scientific information about why such forests are an important buffer against the looming effects of climate change.

To a greater extent than has been understood, old forests, in particular, trap and store ("sequester") vast amounts of carbon for centuries while also producing oxygen (thus serving as the planet's air filtration system). Moreover, intact forest ecosystems provide habitat for many species and serve as a refuge for wildlife forced to migrate in response to climate change. And, in a world where water difficulties will be exacerbated by climate change, undisturbed forests play a critical role in preserving high-quality water. Therefore, prudent forest stewardship begins with protecting what little remains of intact forests so the essential services they provide will continue to sustain us and our descendants.

Fortunately, our nation has shown foresight and wisdom by protecting some of our most intact forests. Enactment of the 2001 Roadless Area Conservation Rule was one of the most important forest conservation steps in a century. This landmark policy was put in place to protect nearly 60 million acres of national forest that, while undeveloped, had no uniform protections to ensure their survival. Along with official wilderness areas, national parks, and national wildlife refuges, roadless areas in national forests house much of the country's last intact forests—and offer hope in a world facing climate change.

This white paper also includes sidebar references as a bridge between faith and science. Whether it comes from a curiosity about how nature works or a deep appreciation of the natural world's spiritual significance, these two worldviews are united through a sense of wonder and respect for the web of life. Such unity offers further hope for finding solutions to the biodiversity crisis, exacerbated by climate change, that is currently engulfing our planet's life-support systems.

Roadless Areas in National Forests Are Nature's Carbon Sponge

"God saw everything that He had made, and indeed it was very good."

—Genesis 1:31

All forests are important in their ability to absorb and store carbon: Forests in the United States offset about 10 percent of all U.S. carbon emissions annually.[1] They sequester vast amounts of carbon dioxide and can store it for centuries in their vegetation, massive tree trunks, and rich soils.[2]

We are now learning that older, intact forests, such as those in national forest roadless areas, are among the world's champions in storing carbon.[3] For example, roadless areas are estimated to contain about 445 million tons of sequestered carbon.[4]

Though their measurements may differ, several studies agree on a central point: Older forests, those more than 100 years old, are particularly effective in storing carbon. Udall and Bates used simulation models to estimate that intact forests can sequester 25 to 80 times as much carbon dioxide as logged areas.[5] Smithwick estimated that "managed forests in temperate regions may contain as little as 30% of the living tree biomass and 70% of the soil biomass of soil carbon found in old-growth temperate forests."[6] Brisbing echoed the idea, stating that "old-growth forests [have been] found to store nearly three times more carbon than" tree plantations that have replaced them.[7]

This is because old-growth forests continue to accumulate carbon as they age. Many studies are now finding that even mature forests increase in biomass (living plant material).[8] Trees and other plants continue to grow in older forests and sequester carbon; when they die, much of their carbon goes into the soil. Thus, forests up to 800 years old are still carbon sinks (or living carbon sponges) and vital allies in combating climate change.[9]

The undisturbed nature of wild forests improves their effectiveness in storing carbon. Conversely, deforestation and degradation release carbon into the atmosphere.[10] When old forests are cut down, as much as 40 percent of their stored carbon is released into the atmosphere from burning or decay of slash and from transport and manufacture of wood products. This released carbon is not fully offset by planting trees or storing carbon in forest products, because most products are short-lived and many forests are cut down again before they can accumulate the amount of carbon present in unlogged mature forests. Recapturing carbon stored in the original intact forests would take more than 200 years.[11]

"[By Buddhist hermits] it is, precisely, undisturbed, unspoiled nature—the wilderness—that is usually regarded as the most favourable environment for spiritual progress and true happiness."

—Lambert Schmithausen
"The Early Buddhist Tradition and Ecological Ethics" in
Journal of Buddist Ethics

Roadless Areas in National Forests Help Protect Against the Water Impacts of Climate Change

Nobel laureate Albert Szent-Gyorgyi called water "the mother of all life."[12] One of the most worrisome effects of climate change is its projected influence on water and our water supply. Scientists on the Intergovernmental Panel on Climate Change[13] say that "all regions of the world show an overall net negative impact of climate change on water resources and freshwater ecosystems."[14] Varying by area, these influences may include decreased water overall and decreased water quality, increased flooding, and major changes in the timing of seasonal water patterns.[15]

The quality of a region's water is a direct reflection of the health of the land. Because of this, forests are crucial for reducing the negative impact of climate change on water, particularly in forests' ability to help maintain water quality, minimize flooding, and ensure water sources are more present throughout the year.

Water from rain and snow seeps into forest soils. Then it is held, sometimes in soil, sometimes in underground water, and released slowly—much like a sponge holding water until it is needed. This helps minimize flooding and provides a more constant water supply. With less flooding and slower runoff, erosion is inhibited, especially in steep areas. With decreased erosion, water channels remain open rather than being filled or diverted by silt, and water is clean, without sedimentation debris.[6]

Undeveloped, roadless forests are more capable of providing these key water services.[17] In fact, it has been said that "[r]oadless areas may have their greatest value in terms of protecting watersheds that can maintain high water quality and predictable flows throughout the year."[18]

Because climate change is projected to affect water considerably, this is even more crucial now, not only for roadless areas but also for roaded regions and people who live there. For example, more than half the roadless areas in national forests provide water to facilities that treat and distribute drinking water to the public.[19] Moreover, high water quality in forests lifts the human spirit, as almost anytime during the year a hiker in an old-growth forest can hear the bubbling of water in the creeks.

Road Impacts

Roads damage water quality. Road construction increases sedimentation of water supplies from erosion. Roads decrease the amount of porous land that can absorb water and thus affect the amount of subsurface water available to a region over the long term. In times of precipitation, roads "concentrate [water] flow, either on the surface or in an adjacent ditch or channel, and they divert or reroute water from paths it otherwise would take were the road not present."*

The decreased absorption, increased concentration, and water diversion lead to greater flooding and all the damage and erosion that accompany flooding. In addition, roads' effects on habitat for aquatic species is significant, adversely affecting stream health.**

* Gucinski *et al.* 2001
**Trombulak and Frissell 2000

Roadless Areas in National Forests Provide Refuge for Species Coping with Climate Change

"[C]limate change is likely to become one of the most significant drivers of biodiversity loss by the end of the century."[20] Up to 30 percent of the world's species may vanish due to a combination of climate change and unsustainable land use.[21] Plants and animals are affected by climate change as it modifies or destroys habitat, alters food and water sources (sometimes to the point they are no longer available or not there when the animal needs them), and raises temperatures. The web of life has coped with climate changes in the past; however, the speed and extent of climate change today combined with loss and fragmentation[22] of natural areas pose particularly stressful challenges to our wildlife.[23]

To help plants and animals struggling with climate change, we must reduce the severity of stressors unrelated to climate change by providing habitat free of human disturbances; such habitat gives species the space, quiet, food and water, and shelter they require to thrive and raise young. Roadless areas offer this because they feature larger tracts of relatively undisturbed land. This is essential in promoting the movement of organisms, genetic material, and flow of ecological processes and materials across the landscape.[24] Such conditions also can enable a species to survive, sometimes even after it has declined or been eliminated in neighboring roaded areas.[25]

"We the five-fingered beings are related to the four-legged, the winged beings, the spiritual beings, Father Sky, Mother Earth, and nature. We are all relatives. We cannot leave our relatives behind."

—Betty Tso, traditional Navajo

This is one reason why roadless areas still contain some of our more fragile species. Although roadless areas make up only two percent of the land base of the continental United States,[26] independent studies have confirmed their importance in providing high-quality habitat for threatened and other wildlife, as well as strongholds for fish.[27] As noted by the Forest Service, approximately 25 percent of all threatened animal species, 13 percent of threatened plant species, and 65 percent of Forest Service-designated sensitive species are found within roadless areas,[28] including many at-risk North Pacific anadromous[29] fish poplations.[30]

The refuge offered by roadless areas to their native species also benefits other plants and animals, providing new habitat as climate change causes migrations. In fact, climate change already has triggered detectable shifts in wildlife distribution.[31] Roadless areas provide corridors for wildlife to migrate in search of food, cooler climes, and other requirements. Roadless areas also meet these needs. For example, with climate change, wildlife are expected to move north in latitude or higher in elevation where it is cooler. Approximately 60 percent of roadless areas are at elevations of 5,000 to 11,000 feet (Forest Service 2000:3-2),[32] and these mid-to-upper, cooler elevations provide important refuge for such climate-sensitive species as wolverines, pikas, and bighorn sheep.

In addition, roadless areas mitigate the diverse and persistent ecological effects of roaded regions by providing a refuge (or population source area) from which wildlife can build more stable population densities,[33] and these source areas then help restore plants and animals in degraded territory. This continual repopulation of species back into roaded areas is essential to maintenance of populations. It may be especially important for "highly mobile animals with large body size [because they] often occur at lower densities and have lower reproductive rates and as a result, are less able to rebound from small population size."[34]

"But ask the animals, and they will teach you; the birds of the air, and they will tell you; ask the plants of the earth, and they will teach you; and the fish of the sea will declare to you. Who among all these does not know that the hand of the LORD has done this?"

—Job 12:7-9

Thomas O'Keefe

Furthermore, roadless areas' role in water quality has important ramifications for fish. Climate change will affect freshwater rivers and streams in a number of ways, including changing vegetation adjacent to streams,[35] increasing water temperature, and decreasing oxygen in the water.[36] Due to less human disturbance in these areas, it is no surprise that our healthiest streams flow through and from roadless areas, and fish populations there are among the healthiest as well. These healthy populations replenish degraded fish populations downstream. A tangible example is that all three of Colorado's native cutthroat trout species depend heavily on roadless areas for habitat and survival.[37] This ability of roadless areas to sustain healthy fish populations will become even more important as climate change stresses water further.

Roadless Areas in National Forests Are Relatively Low Priority for Fuels and Insect Treatments

Climatic conditions such as drought or milder winters contribute to increases in wildfires and insect-related tree mortality. However, because they are less disturbed by roads, logging, and grazing, most roadless areas are not at high risk for fires or insect epidemics, and they are therefore a lower priority for measures to reduce such risks.

Wildfires

About the mid-1980s, wildfire activity increased in the West,[38] especially in mid-elevation forests of the Rocky Mountains. This change has been attributed to climatic factors such as severe drought, although fuels in other regions play a more prevalent role. In spite of such fire increases, wildfires burn considerably less area today than they did before the advent of mechanized fire suppression. The main concern today, however, is risk to property and human life, a threat that is exacerbated by rapid exurban sprawl into the so-called wildland-urban interface, a narrow zone immediately surrounding towns and dwellings.[39]

In addition to the interface zone, roaded areas are generally at greater risk for wildfires compared with roadless areas for the following reasons:[40]

- Timber management can increase ground fuels by leaving behind flammable logging slash and by removing large, fire-resistant trees,[41] replacing them with densely packed and more flammable tree plantations.[42]

- Roads increase the likelihood of human-caused fire ignitions.[43]

- Decades of livestock grazing have replaced native grasses that once carried fires along the ground (cool or low-burning fires) with trees and shrubs that now carry fires into tree crowns.[44]

Thus, restoration-based treatments, including fuels reduction (thinning), should be directed where they are needed most—the already degraded, fire-prone roaded areas. According to the Forest Service,[45] only about eight million of the 58.5 million acres of roadless lands nationwide present a high fire risk that may require non-commodity-based thinning—the thinning of small trees. In such cases, the Roadless Area Conservation Rule provides sufficient agency discretion to reduce such fuels.[46]

"To live, we must daily break the body and shed the blood of Creation. When we do this knowingly, lovingly, skillfully, reverently, it is a sacrament. When we do it ignorantly, greedily, clumsily, destructively, it is a desecration. In such desecration we condemn ourselves to spiritual and moral loneliness, and others to want."

—*Wendell Berry,*
The Gift of Good Land

Insect Outbreaks

Insect outbreaks have been part of the normal cycle in forests for millennia; thus, trees have co-evolved with insects by developing natural defenses. (For example, trees can sometimes overwhelm attacks by trapping insects in sap before they do harm.) Insects also serve as essential strands in an interconnected web of life, vital to the proper functioning of forest ecosystems by providing important services such as pollination and decomposition of standing dead and downed trees. A few insect species cause the bulk of tree mortality, but tree mortality also is part of a forest's natural cycle of life and death. Dead trees are the lifeline of food webs and provide much-needed habitat for wildlife (woodpeckers, bats, and parasitic wasps, for example) that in turn help keep destructive insects in check.[47] However, there are certainly concerns over insect damage turning green forests into areas dominated by tree death, especially in the Rockies, where recent epidemics have prompted calls for increased remedial measures. These insect outbreaks are driven mostly by such climatic factors as severe drought, which stresses trees and predisposes them to insect attacks, and by climate change, which is allowing more insects to survive milder winters.[48]

Prudent reactions to insect outbreaks need to recognize the complexity of such situations. Although it is widely believed that insect outbreaks set the stage for severe forest fires, scant evidence of this association exists, particularly for forest types common to the Rockies such as lodgepole pine and spruce-fir associations.[49] Building roads into roadless areas and logging in the backcountry will not prevent insect outbreaks or stop them once they have begun.[50] Remedial measures such as thinning of overstocked forests may prove beneficial in certain forest types (e.g., low-elevation, degraded ponderosa pine), but these conditions are less prevalent in roadless areas. Like fires, the vast majority (71 percent) of areas at risk for insect outbreaks are in the roaded landscape.[51]

Conclusion

Wild nature contributes greatly to life-sustaining values by providing a myriad of benefits. Roadless areas, in particular, are a priceless sanctuary for the human spirit to grow and reconnect to the natural world, which is increasingly important in this ever-expanding sea of development. They also offer hope that future generations will be able to marvel in their magnificence, and national forest roadless areas are a form of "insurance" to reduce the consequences of climate change, a multifaceted role that is increasingly appreciated. When such forests are developed, however, these benefits can be thwarted.

"Let the heavens be glad, and let the earth rejoice; let the sea roar, and all that fills it; let the field exult, and everything in it. Then shall all the trees of the forest sing for joy before the LORD."

—Psalm 96:11-13

Therefore, a thorough climate change strategy must protect roadless forests, in order for humanity to assist nature in getting the natural world through the climate change bottleneck. One of the best ways to do this is through a fully functioning Roadless Area Conservation Rule that applies to all national forest roadless areas. In May 2010, the Obama administration extended for one year the moratorium on extraction in most roadless areas. Let us continue to be grateful that enough of these forests are left to make a difference, and let us be wise stewards in our care of them.

"[T]he leaves of the tree are for the healing of the nations."

—Revelation 22:2

John McCarthy/The Wilderness Society

Addendum 1: The 2001 Roadless Area Conservation Rule[52]

In 2001, one of the single most important forest conservation acts in a century protected roadless areas in national forests from logging and road building—through the 2001 Roadless Area Conservation Rule. The following describes this landmark conservation policy and how it was developed.

About one-third of the United States is public land, and most of this nearly 650 million acres is woodland in national parks, national forests, and wildlife refuges. About a sixth of this public land (110 million acres) is significantly protected by the Wilderness Act. The remaining federal public lands are somewhat protected from development, but they also are available for logging, mining, grazing, and other uses.

Our national forests contain nearly 60 million acres without roads, an area about the size of Oregon. Now known as Inventoried Roadless Areas, these national forest lands are roadless parcels of 5,000 acres or more in the West and 1,000 acres or more in the East (with the vast majority in the West). They constitute two percent of the U.S. land base and about 30 percent of all national forests. Before enactment of the 2001 Roadless Area Conservation Rule, these areas had not yet been logged and thus typically had no roads.

"On his trip to Mt. Katahdin, Thoreau looked around at the uncut miles and said . . . 'It was a specimen of what God saw fit to make this world.' The earth is a museum of divine intent."
—*Bill McKibben,* The End of Nature

In 1972, the U.S. Forest Service conducted the first systematic inventory of national forest roadless areas, known as the Roadless Area Review and Evaluation (RARE I), to determine their suitability for Wilderness Act protections. Numerous groups questioned the adequacy of RARE I. M. Rupert Cutler, Assistant Secretary of Agriculture in the Carter administration, directed the Forest Service to conduct a new evaluation, and RARE II was completed in 1979. After RARE II, roadless areas had a unique identity and legitimacy.

After RARE I and II, proposals to log and build roads in Inventoried Roadless Areas were commonly contested by environmental groups. Citizen suits succeeded in limiting road building and logging in roadless areas, even though timber harvest in national forests continued to increase, peaking in 1989. During this time, the Forest Service faced a dilemma: If not for continued logging, how should roadless areas be managed? The agency's vision for roadless areas proved to be murky and uncertain. Then, in 1998, a dramatic turn of events occurred: Forest Service Chief Michael P. Dombeck declared a temporary moratorium on new roads in national forest roadless areas.

In October 1999, as this moratorium was about to expire, President Bill Clinton directed the Forest Service to develop regulations providing long-term protection for roadless areas in national forests. In May 2000, a proposed rule was published addressing more than 58 million acres of roadless areas. Public involvement and comments in this process were the largest in Forest Service history. A final roadless rule was published in January 2001.

According to the rule, there was to be no further road construction or timber harvest in national forest roadless areas. However, the policy provided needed flexibility to address emergencies such as fire. For the first time, roadless areas seemed to have a secure future against further erosion of ecological integrity and degraded habitats. In addition, after years of litigation and uncertainty, Forest Service staff finally had a firm, consistent, and clear vision for managing roadless areas.

Upon taking office, the administration of George W. Bush sought to undo the 2001 national roadless rule by delegating to the states the option of protecting roadless areas. However, the many members of the public who support protection of roadless areas and the conservation community largely held the line. And in May 2010, the Obama administration approved a one-year extension of the moratorium on logging, mining, and road building in most roadless areas. At this time, therefore, the majority of roadless areas in national forests stand as a bulwark against climate change.

Addendum 2: The Problem with Roads

"Is it not enough for you to feed on the good pasture? Must you also trample the rest of your pasture with your feet? Is it not enough for you to drink clear water? Must you also muddy the rest with your feet?"

—Ezekiel 34:18

Roads have benefits. They enable commerce and improve access and travel.[53] Some roads, such as the Blue Ridge Parkway, have a beauty unto themselves.

However, roads carry a cost and liability that cannot be ignored. Roads on public lands are expensive for taxpayers to maintain and replace.[54] And they have many environmental consequences that are increasingly apparent, because the human disturbance and forest fragmentation they cause are intimately linked.[55] These consequences can be severe and persist as long as the roads exist, and it does not take much in the way of roads to see impacts.[56]

For example, fragmentation—the carving of lands into smaller pieces or "forest islands"—and smaller islands in general have fewer species. Even relatively narrow forest roads can directly produce such fragmentation, limiting the movement of organisms, genetic material, and flow of ecological processes and materials across the landscape.[57]

On the other hand, roadless areas contain larger portions of interior habitat that avoid much of this fragmentation and human disturbance. Such areas contribute to forest integrity in many ways[58] that are increasingly important in the context of climate change.

Addendum 3: Economic Benefits from Roadless Areas

"For in the true nature of things, if we rightly consider, every green tree is far more glorious than if it were made of gold and silver."

—Martin Luther

By preserving roadless areas in national forests, we forgo the economic benefits of logging, mining, grazing, agriculture, and urban development. But forgoing logging in all national forest roadless areas would decrease timber harvest less than 0.5 percent of total U.S. production.[59]

Alternatively, there are large economic benefits to roadless areas. Ecosystem services—climate regulation, water regulation, waste treatment, refuge for species, food production, and recreation—are unique to, or enhanced by, roadless character and have enormous value.[60] Intact forest ecosystems are healthier and more resilient to climate change and other disturbances than those disturbed by roads and logging.[61] In addition, the 58 million acres of roadless areas in national forests attract an estimated 14.6 million recreation-days annually with an economic value of about $600 million.[62] Moreover, the economic contribution of hunting and fishing in national forest ecosystems is substantial—$1.3 billion to $2.1 billion for hunting and $1.4 billion to $2.9 billion for fishing nationwide.[63]

"[W]e have a lot of work to do to have harmony and peace….We are all in this 'leaky canoe' together so we need to be a united force to be reckoned with and we will keep on keeping on until our 'hearts are on the ground.' "

—Taowhywee, Agnes Baker Pilgrim
Takelma Indian Elder,
Confederated Tribes of Siletz

Put simply, roadless areas can generate jobs and income because of their scenic beauty and quality-of-life benefits. They attract businesses and thus help diversify local economies.[64] They provide key ecosystem services and places not only for fishing and hunting but also room to roam. Finally, they make surrounding regions attractive places in which to live, work, and play.

Chuck Pezeshki

Notes

1. U.S. Congressional Research Service Report, Carbon Sequestration in Forests (RL31432; Aug. 6, 2009), by Ross Gorte.
2. Trees are huge plants, and plants get needed energy through photosynthesis. In photosynthesis plants convert water and carbon dioxide into the sugars they use for energy plus the oxygen they release into our air. In this process, carbon is stored. Trees are about 50 percent carbon. Food and Agriculture Organization of the United Nations, "Deforestation causes global warming," accessed October 2010, www.fao.org/newsroom/en/news/2006/1000385/index.html. And the many other plants in forests also store substantial carbon. As trees and other plants die and fall to the soil, the soil is enriched as carbon is stored in the soil.
3. Erica A.H. Smithwick, Mark E. Harmon and James B. Domingo, "Changing Temporal Patterns of Forest Carbon Stores and Net Ecosystem Carbon Balance: the Stand to Landscape Transformation," Landscape Ecology 22 (2007): 77-94. Sebastian Luyssaert, E.-Detlef Schulz, Annett Börner, Alexander Knohl, Dominik Hessenmoller, Beverly E. Law, Philippe Ciais and John Grace, "Old-growth forests as global carbon sinks," Nature 455 (2008): 213-215. Heather Keith, Brendan G. Mackey and David B. Lindenmayer, "Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon dense forests," Proceedings of the National Academy of Sciences 106(28) (2009): 11635-11640.
4. John B. Loomis and Robert Richardson, "Economic Values of Protecting Roadless Areas in the United States," (analysis prepared for The Wilderness Society and Heritage Forests Campaign, 2000), 24 ("Birdsey and Heath (1995) estimated that an average acre of public forest land sequesters about 31.45 tons of carbon per acre just in the trees.")
5. Brad Udall and Gary Bates, "Climatic and Hydrologic Trends in the Western U.S.: A Review of Recent Peer-Reviewed Research," Intermountain West Climate Summary, January 2007.
6. Erica A.H. Smithwick , Mark E. Harmon, Suzanne M. Remillard, Steven A. Acker and Jerry F. Franklin, "Potential Upper Bounds of Carbon Stores in Forests of the Pacific Northwest," Ecological Applications 12(5) (2002): 1303-1317.
7. S.M. Brisbing, "*Carbon dynamics of old-growth and managed fire-dependent forests in the Northern Rockies" (M.S. diss., University of Montana, 2008).*
8. Tara Hudiburg, Beverly Law, David P. Turner, John Campbell, Dan Donato and Maureen Duane, "Carbon dynamics of Oregon and Northern California forests and potential land-based carbon storage," Ecological Applications 19(1) (2009): 163-180. Luyssaert , 213-215.
9. Luyssaert, 213-215.
10. 1Keith, 11635-11640.
11. 1Mark E. Harmon, William K. Ferrell and Jerry F. Franklin, "Effects on Carbon Storage of Conversion of Old-Growth Forests to Young Forests," Science 247 (1990): 699-702.
12. Albert Szent-Gyorgyi, "Oxygen, energy transfer, and vitamins" (Nobel lecture, Dec. 11, 1937), http://nobelprize.org/nobel_prizes/medicine/laureates/1937/szent-gyorgyi-lecture.pdf.
13. "The Intergovernmental Panel on Climate Change is the leading body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socioeconomic consequences. The IPCC is a scientific body. It reviews and assesses the most recent scientific, technical and socioeconomic information produced worldwide relevant to the understanding of climate change." Intergovernmental Panel on Climate Change, "Intergovernmental Panel on Climate Change," accessed October 2010, www.ipcc.ch/organization/organization.htm.
14. U.S. Environmental Protection Agency, "Climate Change – Health and Environmental Effects, Water Resources," accessed October 2010, www.epa.gov/climatechange/effects/water/index.html#ref.
15. An anticipated tripling of water consumption levels by 2050 in places like Colorado underscores the need to protect roadless areas as climate change triggers more frequent and longer-lasting droughts. Colorado Water Conservation Board, Colorado Department of Natural Resources, Colorado's Water Supply Future, State of Colorado 2050 Municipal and Industrial Water Use Projections (draft report, June 2009). Udall, "Climatic and Hydrologic Trends in the Western U.S."
16. 16 Richard T.T. Forman and Lauren E. Alexander, "Roads and Their Major Ecological Effects," Annual Review of Ecology and Systematics 29 (1998): 207-231.
17. Scott Black, Dominik Kulakowski, Barry R. Noon and Dominick A. DellaSala, "Insects and Roadless Forests: A Scientific Review of Causes, Consequences, and Management Alternatives" (unpublished synthesis prepared for the National Center for Conservation Science & Policy and the Xerces Society for Invertebrate Conservation, 2010).
18. Black, "Insects and Roadless Forests."
19. USDA Forest Service, Forest Service Roadless Area Conservation Draft Environmental Impact Statement (Washington, D.C., 2000), 3-50. Conservation Biology Institute, "Scientific Basis for Roadless Area Conservation," accessed October 2010, http://consbio.org/what-we-do/scientific-basis-for-roadless-area-conservation.
20. United Nations Environment Programme, Convention on Biological Diversity, "Climate Change and Biological Diversity, Introduction," accessed October 2010, www.cbd.int/climate/intro.shtml.
21. United Nations Environment Programme "World Environment Day 2010, The State of the Planet's Biodiversity," accessed October 2010, www.unep.org/wed/2010/english/biodiversity.asp.
22. Fragmentation is the breakup of large, intact parcels (e.g., from clear-cut logging and road building) into smaller, more isolated tracts that begin shedding sensitive species.
23. United Nations Environment Programme, Convention on Biological Diversity, "Climate Change and Biological Diversity." David A. Fahrenthold, "Climate Change Brings Risk of More Extinctions," Washington Post, Sept. 17, 2007.
24. David G. Haskell, "Effects of Forest Roads on Macroinvertebrates Soil Fauna of the Southern Appalachian Mountains," Conservation Biology 14(1) (2000): 57-63.
25. Robert L. DeVelice and Jon R. Martin, "Assessing the Extent to Which Roadless Areas Complement the Conservation of Biological Diversity," Ecological Applications 11(4) (2001): 1008-1018.
26. USDA Forest Service, "Roadless Area Conservation Rulemaking Facts," accessed October 2010, http://fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5137368.pdf.
27. James R. Strittholt and Dominick A. DellaSala, "Importance of roadless areas in biodiversity conservation in forested ecosystems: a case study—Klamath-Siskiyou ecoregion, U.S.A.," Conservation Biology 15(6) (2001): 1742-1754. DeVelice, 1008-1018. Colby Loucks, Nicholas Brown, Andrea Loucks and Kerry Cesareo, "USDA Forest Service roadless areas: potential biodiversity conservation reserves," Conservation Ecology 7(2) (2003), www.ecologyandsociety.org/vol7/iss2/art5/main.html. Keith Curley and David Petersen, "Where the Wild Lands Are: Colorado—The Importance of Roadless Areas to Colorado's Fish, Wildlife, Hunting & Angling" (report produced by Trout Unlimited). Jonathan L. Gelbard and Susan Harrison, "Invasibility of Roadless Grasslands: An Experimental Study of Yellow Starthistle," Ecological

Applications 15(5) (2005): 1570-1580. James R. Strittholt, Dominick A. DellaSala, Eric Fernandez, Gerald Heilman and Pamela A. Frost, "Oregon's Legacy Wild Forests. Conservation Value of Oregon's Inventoried Roadless Areas" (report prepared for the Conservation Biology Institute, Oregon Natural Resources Council, and World Wildlife Fund, 2003).

28. Michael P. Dombeck, Christopher A. Wood and Jack Edward Williams, From Conquest to Conservation: Our Public Lands Legacy (Island Press, 2003), 99.
29. Anadromous fish live mainly in the ocean but breed in freshwater.
30. See Friends of the Clearwater, "Roadless Areas," accessed October 2010, www.friendsoftheclearwater.org/book/export/html/72.
31. Linda A. Joyce, Curtis H. Flather and Marni Koopman, "Final Project Report, Analysis of Potential Impacts of Climate Change on Wildlife Habitats in the U.S." (report for the Doris Duke Wildlife Habitat Policy Research Program, 2008).
32. Strittholt, "Importance of Roadless Areas in Biodiversity Conservation," 1742-1754.
33. DeVelice, 1008-1018.
34. Black, "Insects and Roadless Forests."
35. Riparian areas act as a biological oasis for wildlife activity, particularly in dry regions.
36. Ashley D. Ficke, Christopher A. Myrick and Lara J. Hansen, "Potential impacts of global climate change on freshwater fisheries," Reviews in Fish Biology and Fisheries 17(4) (2007). Richard Hauer, Jill S. Baron, Donald H. Campbell, Kurt D. Fausch, Steve W. Hostetler, George H. Leavesley, Peter R. Leavitt, Diane M. McKnight and Jack A. Stanford, "Assessment of climate change and freshwater ecosystems of the Rocky Mountains, USA and Canada," Hydrological Processes 11 (1997): 903-909.
37. Curley and Petersen, "Where the Wild Lands Are: Colorado."
38. A.L. Westerling, H.D. Hidalgo, D.R. Cayan and T.W. Swetnam, "Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity," Science 313 (2006): 940-943.
39. Dominick A. DellaSala, Jack E. Williams, Cindy Deacon Williams and Jerry F. Franklin, "Beyond Smoke and Mirrors: A Synthesis of Fire Policy and Science," Conservation Biology 18 (2004): 976-986.
40. USDA Forest Service, Forest Service Roadless Area Conservation Draft Environmental Impact Statement (Washington, D.C., 2000).
41. For example, large, mature ponderosa pine trees with thick insulating bark are more fire resistant.
42. Dennis C. Odion, Evan Frost, James R. Strittholt, Hong Jiang, Dominick A. DellaSala and Max A. Moritz, "Patterns of Fire Severity and Forest Conditions in the Western Klamath Mountains, California," Conservation Biology 18 (2004): 927-936.
43. Dominick A. DellaSala and Evan Frost, "An Ecologically Based Strategy for Fire and Fuels Management In National Forest Roadless Areas," Fire Management Today 61(2) (2001): 12-23.
44. Ibid.
45. USDA Forest Service, Forest Service Roadless Area Conservation Draft Environmental Impact Statement (Washington, D.C., 2000), 2-24.
46. Ibid. USDA Forest Service, Forest Service Roadless Area Final Environmental Impact Statement (Washington, D.C., 2000). USDA Forest Service, "Roadless Area Conservation Rulemaking Facts," accessed October 2010, http://fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5137368.pdf.
47. DellaSala, "An Ecologically Based Strategy for Fire and Fuels Management." Black, "Insects and Roadless Forests."
48. Black, "Insects and Roadless Forests."
49. Ibid.
50. Ibid.
51. USDA Forest Service, Forest Service Roadless Area Conservation Draft Environmental Impact Statement (Washington, D.C., 2000), 3-108.
52. James R. Furnish, former Deputy Chief of the National Forest System, U.S. Forest Service, unpublished document, July 2010.
53. More than 4 million miles of roads cross the continental United States, eclipsing by 1 million miles the total length of the nation's streams. Kurt H. Ritters and James D. Wickham, "How far to the nearest road?" Frontiers in Ecology and the Environment 1(3) (2003): 125-129. This extensive road system has made it possible to drive within a mile of more than 80 percent of all lands within the continental United States with only 3 percent of the nation more than three miles from the nearest road. While the Forest Service has 386,000 miles of (classified) Forest System roads under its jurisdiction, Forest Service lands also contain an additional 137,000 miles of roads within their boundaries, including 54,600 miles of public roads, 22,400 miles of private roads and 60,000 miles of unclassified, unauthorized roads. This puts the total number of roads fragmenting habitat and damaging watersheds and streams at approximately 523,000 miles within the national forests." Wildlands CPR, "Understanding the New National Forest System Road Management Strategy," accessed October 2010, www.wildlandscpr.org/understanding-new-national-forest-system-road-management-strategy. Just the 386,000 miles of classified Forest Service roads are enough to circle the planet at the equator more than 15 times.
54. In 2000, the Forest Service had accumulated a growing $8.4 billion (conservative estimate) backlog in deferred maintenance and road reconstruction making it difficult to keep pace with existing roads let alone build new ones into pristine areas. USDA Forest Service, "Road Management Website, List of Questions," accessed October 2010, www.fs.fed.us/eng/road_mgt/qanda.shtml.
55. Strittholt, "Importance of Roadless Areas in Biodiversity Conservation in Forested Ecosystems: A Case Study—Klamath-Siskiyou Ecoregion." Roads provide access for activities such as logging, mining, grazing, agriculture, and urban development. They also lead to (1) increased erosion/sedimentation and air and water pollution; (2) spread of invasive species; (3) wildlife mortality from collisions with vehicles; (4) avoidance of roads by wildlife and destruction and fragmentation of wildlife habitat (the breaking apart of large tracts of forests into smaller isolated parcels that begin losing sensitive species); and (5) increased risk of fire (USDA 2000 Table 3-21). See Stephen C. Trombulak and Christopher A. Frissell, "Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities," Conservation Biology 14(1) (2000): 18-30. Gerald E. Heilman Jr., James R. Strittholt, Nicholas C. Slosser and Dominick A. DellaSala, "Forest Fragmentation of the Conterminous United States: Assessing Forest Intactness Through Road Density and Spatial Characteristics," Bioscience 52(5) (2002): 411-422.
56. For instance, many studies have substantiated that about 0.8 miles of road per square mile of land (0.6 km/km2) seems to be a threshold for healthy wildlife populations. Large mammals and birds such as wolves, mountain lions, grizzly bears, pine martins, and spotted owls are part of a list of those displaced. Because many national forest lands have more than five miles of logging road per square mile, it's understandable that local wildlife and fish populations can be impaired, even eliminated. Black, "Insects and Roadless Forests."
57. Haskell, 57-63 (and the special feature on roads in Conservation Biology, same edition).
58. A number of independent studies have confirmed roadless areas' importance in providing high-quality habitat for threatened and big-game (huntable) wildlife, concentrations of old-growth forests, and undeveloped strongholds for fish, and, due to the absence of roads and other disturbances, a buffer against invasive species. Strittholt, "Importance of Roadless Areas in Biodiversity Conservation in

Forested Ecosystems: A Case Study—Klamath-Siskiyou Ecoregion." DeVelice, 1008-1018. Loucks, www.ecologyandsociety.org/vol7/iss2/art5/index.html. Curley and Petersen, "Where the Wild Lands Are: Colorado." Gelbard, J.L., and S. Harrison. 2005. Gelbard, "Invasibility of roadless grasslands." Strittholt, J.R., D.A. DellaSala, E. Fernandez, G. Heilman and P.A. Frost. 2003. Strittholt, "Oregon's Legacy Wild Forests." Also, there is general consensus that a ten-fold increase in area leads to doubling the number of species. Edward O. Wilson, Naturalist (Island Press, 1994), 248.

59. USDA Forest Service, "Roadless Area Conservation Rulemaking Facts," accessed October 2010, http://fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5137368.pdf.
60. Robert Costanza, Ralph D'Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V. O'Neil, Jose Paruelo, Robert G. Raskin, Paul Sutton and Marjan van den Belt, "The value of the world's ecosystem services and natural capital," Nature 387 (1997): 256.
61. Tom Turner, Roadless Rules: The Struggle for the Last Wild Forests (Washington, D.C.: Island Press, 2009).
62. Douglas Krieger, "Economic Value of Forest Ecosystem Services: A Review" (analysis prepared for The Wilderness Society, 2001).
63. Ibid.
64. Southwick Associates, "Historical Economic Performance of Oregon and Western Counties Associated with Roadless and Wilderness Areas" (study prepared for the Oregon Natural Resources Council and the World Wildlife Fund, 2000). Loomis, "Economic Values of Protecting Roadless Areas in the United States."