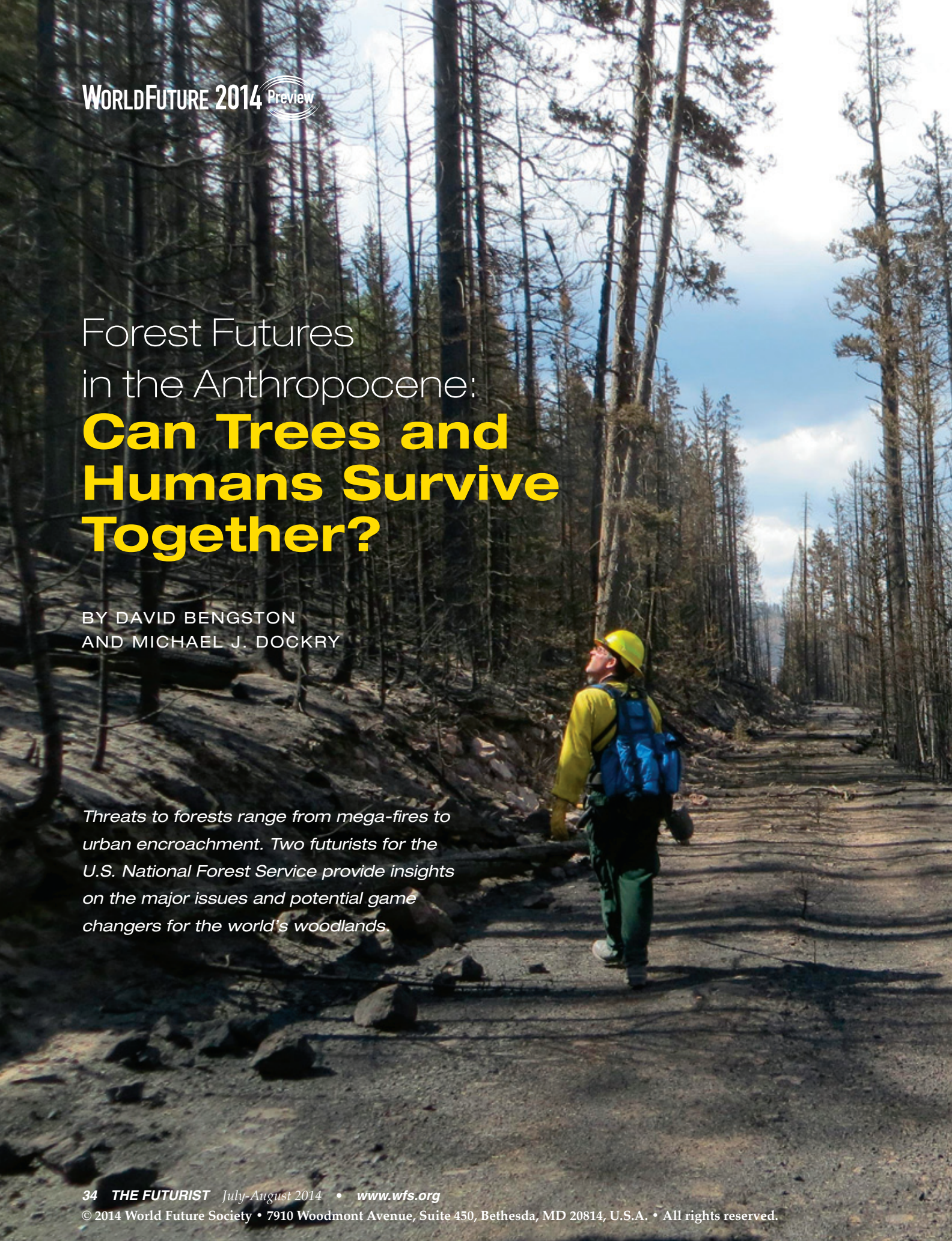


Forest Futures in the Anthropocene: Can Trees and Humans Survive Together?

BY DAVID BENGSTON AND MICHAEL J. DOCKRY

Threats to forests range from mega-fires to urban encroachment. Two futurists for the U.S. National Forest Service provide insights on the major issues and potential game changers for the world's woodlands.

Foresters and futurists share a long-range perspective. The lengthy growing cycle of trees has compelled foresters to plan decades and even hundreds of years ahead, in contrast to the short-term view of most fields. The interconnected nature of forest ecosystems has also given foresters—like futurists—a systems perspective. As the American naturalist John Muir said, "When one tugs at a single thing in nature, he finds it attached to the rest of the world."

The world's forests range from sparsely populated wilderness to urban forests, from lush tropical rain forests to the vast boreal forests of the North. Thirty-one percent of the Earth's land area and 30% of the United States is covered by forests. Healthy forests provide a wide range of ecosystem services, natural assets that are vital to human well-being and livelihood. For example, forests sequester carbon from the atmosphere; contain about 90% of the Earth's terrestrial biodiversity; provide a home for wildlife; protect watersheds; regulate the water cycle; create scenic landscapes; provide cultural, recreational, and spiritual opportunities; and produce goods such as timber, fuelwood, fodder, and other non-timber forest products. The list of forest goods and services goes on *ad infinitum*.

Despite their importance, the future of forests is by no means clear in what some have called the "Anthropocene," the epoch we are entering in which the impacts of human activities increasingly dominate Earth's ecosystems. The actions of people have always influenced forests, but the increased pace and magnitude of change in human systems poses many challenges for these ecological life-support systems.

This article looks at some of the major issues and factors affecting forests in the decades ahead: deforestation, mega-fires, urban forests and growing urban populations, the end of wilderness, and water. Potential "game changers" for forest ecosystems include bioenergy and wood-based nanomaterials, synthetic biology, and runaway climate change.

Member of the U.S. Forest Service's Burned Area Emergency Response (BAER) assessment team examines damage in a 2013 fire in the Santa Fe National Forest, New Mexico.

U.S. FOREST SERVICE PHOTO

Major Issues Shaping Forest Futures

• **Deforestation and land use change.** The future of forests at the most basic level depends upon maintaining forests as forests and not converting them to agriculture, ranching, or urban and suburban land uses. After the last ice age, forests expanded to cover about half the world's land area. According to the most recent UN Food and Agriculture Organization estimates, 31% of the Earth's surface is covered by forests, amounting to about 4 billion hectares. The five countries with the most forest area today are Russia, Brazil, Canada, the United States, and China. These countries account for half of the world's forests.

Forests and deforestation play important roles in the carbon cycle and climate change. Some scientists estimate that forests sequester around 40% of human-made carbon emissions annually, but forests also release carbon when deforested. Globally, about 17% of carbon-dioxide emissions result from tropical deforestation and forest degradation—more than transportation-related greenhouse gas emissions.

Between 2000 and 2012, 1.8 million square kilometers of forest globally were converted to non-forest use, while only 0.8 million square kilometers were converted back into forest. Cumulatively, forests are being replaced by non-forest land conversion across the globe. Tropical deforestation continues every year, despite the fact that deforestation rates have been decreasing. Africa, South America, and Oceania have the dubious distinction of the largest net loss of forest cover, while North America and Europe show modest increases or little change in forested area. Leading the world in the rates of planting forests, Asia shows strong positive change in forest

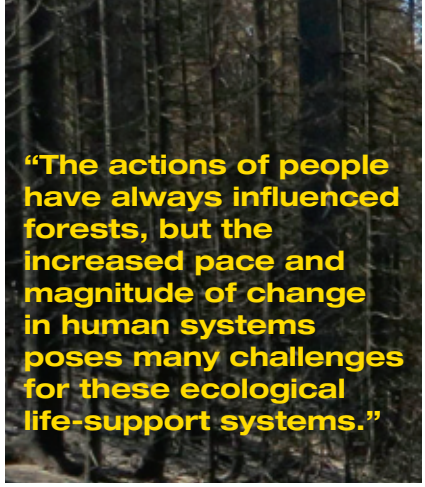
cover. Planted forests are increasing globally and currently account for 7% of the forested area.

The future of forests and deforestation is complex because it is a function of political, economic, ecological, technological, and social processes. If the net loss of forests continues, the world's forests will continue to become degraded, with resulting decreases in biodiversity, ecosystem functioning, and feedbacks that accelerate climate change. Another possible outcome could be the rise of the planted forest if the rest of the world follows Asia's lead. Research is unclear on whether or not plantation forests decrease pressure on native forests, so it is uncertain if planted forests will replace native forests or if they will decrease the area deforested.

One thing is clear: If more and more forest area is lost each year, there will be more opportunities for plantation forests to be established.

• **Rise of mega-fires.** Wildfires have increased in frequency, intensity, and area burned in many areas around the world, including the U.S. West. A "perfect storm" of factors is driving future wildfires. First, climate change is creating hotter and drier conditions. Trends of rising temperatures, earlier springs, decreased soil moisture, and drying of biomass fuels are leading to longer and more severe fire seasons.

Second, decades of rapid suppression of wildfires across the globe has resulted in dense, overgrown forests and a massive accumulation of potential fuels for fire. Before the advent of aggressive firefighting in fire-dependent ecosystems, periodic low-intensity fires cleared out much of the forest understory, leaving most trees unaffected.



Third, rapid growth in the number of homes and communities in forested areas will contribute to the risk of wildfire damage to homes and danger to people. In the United States, another 17 million housing units are projected to be built within 50 km of protected areas (national forests and parks, wilderness areas) by 2030. Of these additional homes in and around forests, 12.3 million will be in the U.S. West, a 111% increase since 2010. The fire problem is much more challenging with more people and homes on the landscape.

Fourth, invasive species and diseases have altered forest composition and integrity. Insect outbreaks are weakening trees and leading to widespread tree death in some regions, with the potential to significantly increase fire risk.

Finally, the costs of wildfire management are rising and government budgets are declining. In inflation-adjusted dollars, the U.S. government is spending less today on efforts to reduce potential fuels for wildfire around communities than it did in 2002. Fire-suppression budgets dwarf budgets to proactively reduce fire risks in the nation.

All of these factors are leading to the rise of unusually large and destructive wildfires. These mega-fires are distinguished by the extraordinary scope and scale of their impacts. Only about 0.1% of wildland fires are classified as mega-fires, but they account for about 95% of total area burned and 85% of the total costs of firefighting. The substantial amount of carbon released into the atmosphere and reduction of sequestration capacity resulting from mega-fires is a likely feedback to accelerating climate change.

Projections of future fires are alarming. In the U.S. West, for example, the median annual area burned is predicted to increase by a factor of two to five for just a 1°C (1.8°F) increase in global average temperature. Intergovernmental Panel on Climate Change (IPCC) projections for warming suggest a further 4°C to 6°C global warming by the end of this century. Regardless of the scenario, mega-fires will continue to shape the world's forests in the decades to come.

• **Urban forests and growing urban populations.** While many of us think of forests as being located in remote or rural environments, there is growing recognition of the existence and importance of urban forests. For the first time in human history, more than 50% of the world's population lives in urban areas. By 2050, that could rise to 70%, or 6.4 billion people, largely in developing countries.

OREGON DEPARTMENT OF FORESTRY PHOTO BY J. PRICHER

Fire crew works through the night against the Government Flat Complex Fire near The Dalles, Oregon, which was started by lightning on August 16, 2013. The fire consumed approximately 11,434 acres when the photograph was taken.

U.S. FOREST SERVICE PHOTO

The Kelley Fire in the Sawtooth National Forest near Featherville, Idaho, was started by lightning on August 24, 2013, and had consumed approximately 17,346 acres when the photograph was taken.

Not only will urban forests continue to provide direct ecosystem services to the majority of the world's population, but they also have the potential to foster human community and connectedness to nature. Many academics, indigenous people, and environmentalists argue that connectedness to nature is critical for adapting to and solving the environmental problems of the twenty-first century.

The importance of urban forests cannot be underestimated. Urban forests are valued across the globe for their contributions to air pollution reduction, carbon sequestration, water runoff, and flood control, as well as for their ability to mitigate urban heat sinks. Urban forests provide habitat for animals and plants, and they foster human health and well-being. Urban foraging movements—that is, gathering food and medicine—are emerging across the globe. Urban forests of the future will be critical components of green infrastructure systems.

New research is beginning to study cities as ecosystems that include not only ecological, but also social, cultural, institutional, technological, and economic dimensions. Urban forests are often cornerstones to our urban ecosystems. Research results are not yet consistent for the role urban forests play in biodiversity, but it is clear that urban forests are much more diverse than urban concrete jungles. More research is needed to understand the extent of urban forest cover, urban forest health, urban forest values, and human relationships to urban forests.

• **The end of wilderness?** In everyday language, the term *wilderness* conjures up images of a wild and uninhabited forest. Wilderness also refers to areas that have been officially designated and protected for their relatively untouched natural state. Wilderness in this sense represents the last remnants of truly wild nature. The U.S. Wilderness Act was passed 50 years ago this year. This landmark legislation strongly emphasized the future of wilderness, reflected in language like "enduring," "future generations," and "for the permanent good."

The importance of wilderness now and in the future arises from the unique values provided by these ecosystems: scientific value as a benchmark of naturalness and how healthy forests function; heritage value as a repository of the primeval conditions that shaped us as a species and helped forge our national identities; bequest value as a natural legacy; spiritual and cultural values; and moral obligation to future generations.

Despite common views that wilderness is untouched by humans, wilderness from Yellowstone to the Amazon rain forest has been shaped by human hands over millennia. But in the Anthropocene, human activities are increasingly harming even the most remote places on the planet. For example, glaciologists can pinpoint the upswing in China's industrial growth by pollutants encased in ice cores in the Arctic National Wildlife Refuge in the northeast corner of Alaska.

A host of human-caused environmental stressors are also reshaping once-wild ecosystems. Foremost is climate change, wilderness's greatest challenge. Accelerating climate change in coming decades will profoundly affect wilderness ecosystems. For example, the range of some emblematic species is predicted to shift outside of the protected areas they're named after: Joshua Tree National Park may not support the Joshua trees, and the Sequoia and Kings Canyon National Parks may not contain regenerating giant sequoias. Other wilderness stressors include invasive exotic species, habitat fragmentation in and around wilderness areas, and atmospheric pollution.

Wilderness was identified as a "disappearing future" in the September-October 2013 issue of THE FUTURIST. That forecast seems likely. Wild nature, with its unique values, will be increasingly replaced by a tamer form of nature with a much heavier and negative human imprint.

• **Water.** Water is predicted to be one of the biggest emerging environmental issues of this century. As global climate patterns change, so does the water cycle. Climate models and recent experience show that precipitation patterns will become less predictable and more extreme—from unprecedented droughts followed by unprecedented rain and flooding. In recent years, there have been historic droughts in Asia, Africa, North and South America, and Australia. California is experiencing a drought that could rival the droughts of the Dust Bowl years.

At the same time, historic flooding and storms have cascaded throughout the world. During the winter of 2013-2014, England experienced some of the worst flooding and storm surges in its history. Extreme

flooding and drought can cause food insecurity, decreased water availability, damage to infrastructure, human migrations, and conflicts over natural resources. No country is exempt from these trends. Extreme water events will only increase as climate change progresses.

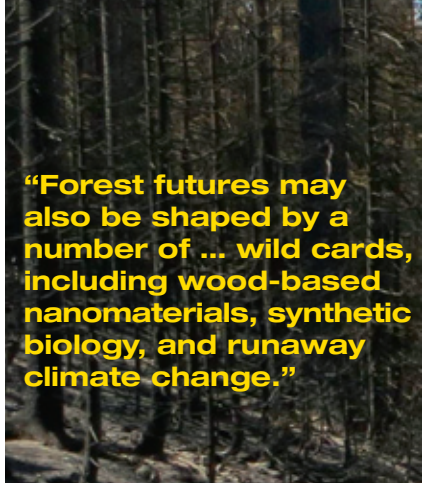
Forests, however, are the world's water regulators. On one hand, forests are negatively affected by extreme precipitation events—trees die from droughts, forests blow down in hurricanes, and flooding washes vegetation down rivers and mountainsides. On the other hand, forests regulate watersheds, prevent water runoff, provide clean surface water, and help resupply underground aquifers.

Forests and agroforestry cropping systems can stabilize and supplement conventional agriculture by making water more available for crops, reducing temperatures, and providing shade. Forests as part of green infrastructure systems could stabilize water supplies and protect against extreme precipitation events.

Potential Game Changers for Forests

Forest futures may also be shaped by a number of potential game changers or wild cards, including wood-based nanomaterials, synthetic biology, and runaway climate change.

• **Advanced energy and materials: Bioenergy and cellulosic nanomaterials.** Forests and agricultural plants have the potential to produce more than a billion tons of renewable, carbon-neutral biomass that could be used to transition into a new global green economy. Forests and forest products could be a fundamental component of the emerging green economy. Forests are truly a renewable resource—trees can be harvested and regrown and harvested again, over and over. Forest products are recyclable and compostable. Forests are carbon sinks, and the products are carbon-neutral.



In recent years, especially for the United States, myriad problems have come together—climate change, invasive species, uncontrolled wildland fire, and changes in international trade—that make it difficult to use forest management to restore ecosystems, to make them more resilient to future environmental change, and to foster economically sustainable businesses. In essence, it is economically difficult to harvest trees at the scale necessary to restore ecosystems that have become overgrown with small trees and shrubs and are being killed by unprecedented insect and disease outbreaks. It simply does not pay to harvest low-value and low-quality trees, yet that is exactly what needs to happen to improve forest health and the struggling forest-products industry.

A potential game changer that would remedy this situation would be the emergence of new markets for high-value but low-quality woody biomass. This is the promise of a forest-based bioenergy, wood-based nanomaterials, and green chemicals. For example, researchers are developing computer screens made from wood-based nanomaterials. Imagine waterproof smartphones that can be composted!

Other researchers are looking to use wood-based nanomaterials to produce solar power and nanosensors in paper and wood products to detect forces, moisture, and chemical pollutants. Still others are working to develop stronger and lighter products that could go into energy-efficient cars, stronger building materials, and coatings for novel and efficient paper products. Forest products researchers and engineers are trying to develop efficient technologies that convert wood into electricity, fuel, and heat. One can envision the emergence of local energy systems based upon renewable woody biomass.

There is new research going on throughout the world to bring many of these new technologies to market. If these efforts are successful, we will be able to produce our energy, chemicals, plastics, and electronics from renewable and carbon-neutral sources—trees.

• **Synthetic biology** is an emerging field with great potential to positively and negatively affect forests and other natural systems in the future. Already moving out of the lab and into commercial applica-

MARISTERRA LEMES, INSTITUTO NACIONAL DE PESQUISAS DA AMAZONIA / NSF

In the Amazon, a mahogany tree is felled. Deforestation rates have decreased, but deforestation continues in South America, which has the world's largest net loss of forest cover along with Africa and Oceania.

© WIM THIERY / UNIVERSITY OF LEUVEN, BELGIUM

Vegetation has replaced felled rain forests in much of the Congo basin. Less rain forest means less evaporation and increased warming. A study by researchers at University of Leuven, Belgium, concludes that deforestation could intensify climate change in the Congo basin by 50%.

tions, synthetic biology is the use of chemically synthesized DNA to create organisms with novel traits—or, as some have described it, "genetic engineering on steroids."

Some believe that synthetic biology will be one of the transformative technologies needed to address many of the most important challenges facing humanity, such as climate change, renewable energy, and sustainable food production. Potential environmental applications include saving endangered species and bringing back extinct ones, using engineered bacterial cells as biological sensors to identify the presence of toxins in the environment, and creating bacteria that can clean up oil spills and other pollutants.

Reforestation could be promoted by using engineered bacteria to stimulate root growth and promote soil stability. It is easy to imagine creating trees with genes engineered to keep them free of disease or to produce desirable wood properties using novel nanomaterials.

But the potential negative effects of synthetic biology have also created concern among some scientists, bioethicists, and public figures. The unintended ecological consequences of synthetic genomes, artificial cells, and engineered life forms are impossible to predict and could be dire. Despite the best efforts to control them, synthetic microorganisms could escape, persist, and spread into natural environments. They might disrupt ecological functions, alter habitats and food webs, or transfer their altered DNA into natural organisms. Some worry that an engineered virus could wipe out entire native populations and wreak havoc with biodiversity.

Synthetic biology has great potential to help conserve forests and the ecosystem services they provide, but it also poses significant ecological risks. Once novel organisms are released into the environment, the genie is out of the bottle. It is critical to assess the risks and effectively regulate the applications of synthetic organisms in order to avoid future ecological calamities.

• **Runaway climate change.** In the prevailing "gradualist paradigm," climate change is viewed as resulting in ecological changes that are cumulative and incremental. Such gradual climate change would result in profound ecological changes over many decades.

An alternative view held by some scientists is that climate change might occur through a combination of gradual and abrupt changes as various tipping points are reached. Positive feedbacks would amplify changes within the climate system, creating a runaway climate change catastrophe not represented in any IPCC scenario.

There are a number of possible tipping points that could lead to runaway climate change. One is the release of trillions of tons of methane from beneath the oceans. The release of methane trapped in frozen sediments is believed to have triggered the Paleocene-Eocene thermal maximum, a period of extreme warming and mass extinction 55 million years ago. Rapidly warming oceans today could destabilize methane sediments and result in another massive release of methane that could raise global temperatures by more than 6°C (10.8°F). The ecological effects of such a temperature rise would be more like dystopian science fiction than scientific thinking about climate change to date.

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The world's forests provide ecosystem services vital for a healthy planet and human well-being. Many challenges will have to be faced to sustain future forests. Some of these challenges are similar to ones forest planners, managers, and policy makers have successfully dealt with in the past; others are new and daunting. Tackling these issues now with the help of foresight is needed to pass on this natural legacy.

Planting a tree or conserving a forest is an act of hope for future generations. ❑

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This article is a preview of their conference presentation at WorldFuture 2014: What If, which will take place July 11-13 in Orlando, Florida.