PERSPECTIVES

Maasai men use telemetry to locate lions as part of the Lion Guardians conservation program in Kenya.

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CONSERVATION AND SOCIETY

Sharing the land between nature and people

Conserving the planet's ecological heritage requires a new level of societal engagement

By **Erle C. Ellis**

Human societies have long reshaped environments to sustain themselves. From bands of hunter-gatherers to agrarian empires to global supply chains, human societies have evolved unprecedented capacities to transform the biosphere, lithosphere, atmosphere, and climate (*1*). Today, the ups and downs of economies and polities shape Earth's ecology as surely as the weather does. Yet even though human societies have never been more globally capable, interconnected, or interdependent, the social institutions, processes, and infrastructures that sustain people and the rest of life on land remain remarkably complex and heterogeneous. From parcels to planet, the management of Earth's limited land is in the hands of nearly 8 billion people with different needs, wants, abilities, perspectives, and social relations. A better future for people and for the rest of nature will depend on bringing all these hands together to shape it.

Most people now live longer, healthier, and more comfortable lives than their ancestors (*2*). Yet the opposite is true for the rest of life on Earth. Space for wild nature has shrunk dramatically, rapid climate warming is posing further threats, and species are going extinct at alarming rates (*3*, *4*). Most people aspire to the modern resource-rich lifestyles responsi-

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ble for these changes. Indeed, as populations quadrupled over the past century, per capita rates of food, energy, and other resource consumption grew even faster, accelerating already massive resource demands (*2*).

Under such conditions, it might seem impossible to create a future where nature and people thrive together over the long term. Yet it is not by using up and destroying environments that human societies gained the capacity to grow and develop over the long term, but rather by evolving ever greater scales of social and material exchange supported by increasingly productive agroecosystems (*1*). Can this capacity to evolve economies of scale be leveraged to create a better future not only for humanity but also for nonhuman nature? How can cooperation across diverse stakeholders toward a common social goal—the conservation of nature—be enhanced?

THE MAKINGS OF A BETTER PLANET

Even as populations grew rapidly in the latter half of the 20th century, more food has been produced per person and per unit of land over time, sustaining progressively richer diets without substantially increasing overall use of Earth's land (see the figure) (*2*). Lands less suitable for large-scale production have been abandoned, leading to woodland recovery in the Eastern United States, parts of Europe, and even in densely populated rural landscapes in China. Over the same period, economic development and urbanization have stimulated rapid declines in rates of population growth. Human populations are now expected to stabilize around 11 billion later this century (see the figure) (*2*).

These trends apply across most of the world, though some less developed regions, including parts of Africa, have lagged. If, however, current trends can be sustained and expanded around the world, there is clear opportunity to create more space for the rest of nature to thrive together with humans over the long term (*1*, *2*). Yet the challenges remain formidable. Agriculture, forestry, settlements and other infrastructures already cover more than half the terrestrial biosphere (*1*). Many of Earth's most biodiverse communities and most endangered species, including mountain gorillas and giant pandas, survive only in small islands of remnant and recovering habitats dispersed within broad oceans of agriculture and cities (*5*). Some habitats critical for conservation remain in remote areas, but the need to expand and interconnect habitats within the shared mosaics of working landscapes is at least as critical.

The future of the nonhuman world thus depends on making cities denser and agriculture more productive while simultaneously making both more wildlife friendly (*5*, *6*). Strategies for achieving this already exist. Community groups, farmers, ranchers, nongovernmental organizations (NGOs), and governments are working together locally, nationally, and regionally to protect endangered species and habitats through monitoring and fencing, equipping roads and other infrastructure with bridges and tunnels to facilitate wildlife movements, and establishing regional corridor networks that enable species to migrate ahead of changing climates (*6*, *7*). Farmers are using best management practices and precision agriculture to minimize agrichemical pollution and engaging in multifunctional landscape-management strategies, including stream buffer plantings and the time-sharing of agricultural fields (*5*).

Efforts are also advancing at global scale. International agreements through the Reducing Emissions from Deforestation and Forest Degradation (REDD+) Programme reward developing countries for decreasing forest conversions, while the Aichi Targets of the Convention on Biological Diversity aim to halve loss of natural habitats and protect 17% of Earth's land by 2020 (*8*). Global supply chain transparency initiatives and voluntary certification of sustainable production have had some success in reducing habitat losses caused by commodity production, including soy and palm oil (*9*).

These nascent efforts to conserve Earth's ecological heritage could be radically expanded while sustaining broad improvements in human social conditions. The greatest challenges to making this happen are not scientific, technical, or economic. They are social and political.

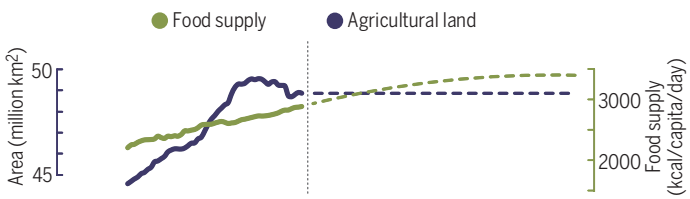
NAVIGATING THE CHALLENGES AND TRADE-OFFS

Sharing this planet fairly with each other and the rest of nature is a collective challenge that demands a new level of societal engagement in conservation (*10*). To achieve this, two questions must be answered. How can people across an entire planet, despite their many differences, be motivated to work together on a common project to conserve Earth's ecological heritage? And how can the burdens and benefits of such a large-scale social project be distributed fairly and equitably across the many diverse people, social groups, and institutions with a stake in Earth's land? Navigating the global land system toward a better future for both nature and people is less about determining science-based targets than about finding ways to negotiate toward and govern such better futures together (*7*, *8*, *11*).

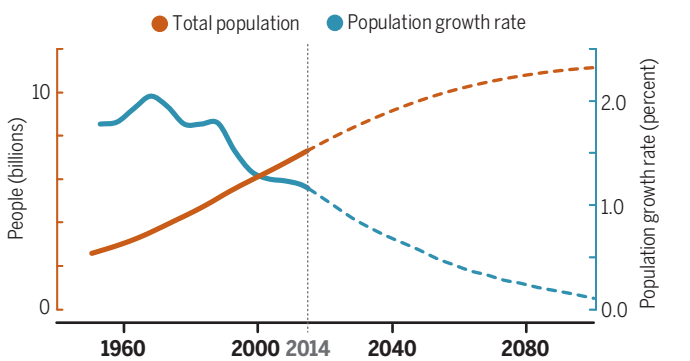
As human populations stabilize, urbanize, and are freed of the daily burdens of survival, social demands and support for conservation and restoration are increasing (*2*, *10*, *12*). If these trends can be sustained, aspirations for conserving and restoring the natural world could become as broadly held and compelling as aspirations for economic development. However, scientific indicators, globally optimized strategies, and "doom and gloom" messaging are unlikely to build trust and foster dialog across social and spatial divides. Appealing to common prosocial values like fairness and ethics in pursuit of broadly understood and socially valued goals is more likely to drive the widespread buy-in needed to reverse the global decline of wild nature (*10*, *11*).

Land use and population trends and projections

In recent decades, global land use for agriculture has stabilized while food supplies rose (*14*). The future trends shown assume no further net increase in agricultural land use and gradual stabilization of net per capita dietary caloric demand.



Since 1950, the global population has grown, but population growth rates have fallen. Median forecasts suggest that the global population will stabilize by the end of the century (*15*).



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PROTECTING NATURE WHILE IMPROVING SOCIAL CONDITIONS

Governing land to meet the competing demands of diverse stakeholders with different needs, abilities, and perspectives is a wicked problem, where trade-offs between production, conservation, and other uses can produce winners and losers, especially under conditions of unequal power (*7*, *11*, *13*). For example, bioenergy demands can displace food production, driving up food prices, while also causing tropical deforestation for cane ethanol or palm and soy biodiesel. Demands for biodiversity conservation and the sequestration of carbon emissions can displace indigenous and vulnerable peoples in the forests of the Global South.

Thus, even widespread success in nurturing and spreading conservation aspirations will not be enough unless they also lead to effective conservation actions that do not unfairly burden the most vulnerable people on Earth. Success will depend on creating and sustaining the social processes, institutions, and strategies needed to make planetary cooperation possible. Critically, it is essential that each of these elements be framed within transparent, equitable, participatory, and adaptive multilevel systems of landscape governance that benefit people as much as they benefit the natural world (*7*, *11*).

Some examples point the way forward. The most diverse megafauna landscapes remaining on Earth—home to lions, elephants, endangered black rhinos, and African wild dogs—are also home to the cattle-raising Maasai people of East Africa. This is no accident. For centuries, their livestock-centered cultural identity proscribed wild game hunting and consumption. Despite this unrivalled capacity for wildlife coexistence, Maasai culture and identity were often ignored by conservationists in the past, creating conflicts among people and wildlife that limited conservation success. Today, local participation and demand for wildlife conservation are advancing through community-based conservation strategies built on indigenous rights and traditional practices, while external investments in conservation by governments and international NGOs are being directed toward local needs, including improved infrastructure, education, and livelihoods.

Another example is provided by the Yellowstone to Yukon initiative, which aims to restore mobility for large carnivores and other species across a mountainous corridor from the United States to Canada. First conceived by conservationists, the initiative soon led to conflicts among stakeholders. Mistrust of conservation-centric stakeholders (such as the NGOs) by land users (farmers, ranchers, and indigenous governments) led to implementation failures. Yet these conflicts were ultimately overcome by establishing a broader participatory governance approach that combines "the needs of people with those of nature" (*7*).

In Europe, the Natura 2000 network of the European Union (EU) is the largest international conservation network on Earth, with nearly 30,000 sites covering nearly 800,000 km^2, or 18% of the EU's land area. The network's widely heralded successes in expanding and strengthening conservation across some of the most intensively used working landscapes on Earth owes much to the EU's strong governance and policy frameworks. Equally important, however, has been the network's embrace of innovative local and regional systems for coordinating conservation and development, including participatory spatial planning, and its sustained efforts to stimulate broader public interest in and demand for biodiversity conservation over the long term.

As these examples show, the call to manage land toward a better future is not a call to end development, but rather a call to develop better. Progress will come when people aspire to live in a world where nature is given enough space to thrive and are ready to cooperate fairly in the hard work and investments needed to make this a reality. The nature we sustain on this planet will ultimately be the nature we work to make space for together. ■

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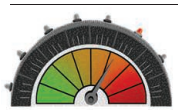

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Mutation hotspots may not be drug targets

Recurrent mutations in tumors can be artifacts of nonrandom mutagenic processes

By **Hannah Carter**

Landmark studies of tumor genomes have revealed considerable intertumoral genomic heterogeneity, characterized by acquired (somatic) mutations and chromosomal aberrations (*1*, *2*). The majority of somatic mutations in tumor genomes are thought to be randomly occurring passenger mutations that do not drive tumorigenesis. However, some are driver mutations, affecting a limited number of genes and pathways that are important for oncogenesis (*1*, *2*). Because random mutations are unlikely to affect the same genomic position, recurrent mutations or "hotspots" are assumed to indicate positive selection for mutations that confer a fitness advantage (*3*). Genes harboring mutational hotspots are often prioritized for drug development and clinical investigation. On page 1251 of this issue, Buisson *et al.* (*4*) show that inappropriate activation of APOBEC3A (apolipoprotein B mRNA editing enzyme catalytic subunit 3A), an enzyme that deaminates cytidine DNA bases and thereby causes mutations, can create mutational hotspots that are independent of tumor cell fitness.

Tumorigenesis is an evolutionary process wherein cells accumulate somatic mutations through errors in normal DNA replication or exposure to mutagenic agents, and these mutations provide the substrate for natural selection (*5*, *6*). Tumor cells with advantageous mutations out-proliferate neighboring cells to create clonal populations with shared mutations that can be detected through DNA sequencing. Large-scale studies of tumor genomes by consortia such as The Cancer Genome Atlas (*2*) have

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