NATIONAL GEOGRAPHIC

7 BILLION

HOW YOUR WORLD WILL CHANGE

NATIONAL GEOGRAPHIC

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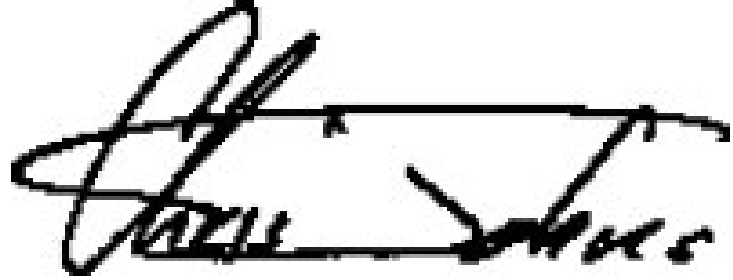
Introduction

The world's population will reach seven billion this year. But you don't need to visit Delhi, India (population 22 million), or China (home to a fifth of the world's people) to grasp the consequences. When I return to Jackson County, Oregon, where I was born, the green fields where I used to cut hay, dig onions, and harvest pears are gone. They have been replaced by subdivisions and big-box stores. This is hardly a surprise given that the population of Jackson County has more than tripled in my lifetime. When I see the rapid development going on in my hometown, I can't help but wonder what the future holds for the rest of the world.

This month we begin exploring that future with a series of stories about population. Environment editor Robert Kunzig starts by sketching out a natural history of population. The issues associated with population growth seem endless: poverty, food and water supply, world health, climate change, deforestation, fertility rates, and more.

Kunzig writes, "There may be some comfort in knowing that people have long been alarmed about population." Some of the first papers on demography were written in the 17th century. It's more than 300 years later, and we are still grappling with the outcome of People v. Planet. We look forward to exploring the topic with you.



Chris Johns, Editor in Chief, *National Geographic* magazine

Chapter 1: Population 7 Billion

BY ROBERT KUNZIG

Robert Kunzig is National Geographic's *senior editor for the environment.*

One day in Delft in the fall of 1677, Antoni van Leeuwenhoek, a cloth merchant who is said to have been the long-haired model for two paintings by Johannes Vermeer—"The Astronomer" and "The Geographer"—abruptly stopped what he was doing with his wife and rushed to his worktable. Cloth was Leeuwenhoek's business but microscopy his passion. He'd had five children already by his first wife (though four had died in infancy), and fatherhood was not on his mind. "Before six beats of the pulse had intervened," as he later wrote to the Royal Society of London, Leeuwenhoek was examining his perishable sample through a tiny magnifying glass. Its lens, no bigger than a small raindrop, magnified objects hundreds of times. Leeuwenhoek had made it himself; nobody else had one so powerful. The learned men in London were still trying to verify Leeuwenhoek's earlier claims that unseen "animalcules" lived by the millions in a single drop of lake water and even in French wine. Now he had something more delicate to report: Human semen contained animalcules too. "Sometimes more than a thousand," he wrote, "in an amount of material the size of a grain of sand." Pressing the glass to his eye like a jeweler,

Leeuwenhoek watched his own animalcules swim about, lashing their long tails. One imagines sunlight falling through leaded windows on a face lost in contemplation, as in the Vermeers. One feels for his wife.

Leeuwenhoek became a bit obsessed after that. Though his tiny peephole gave him privileged access to a never-before-seen microscopic universe, he spent an enormous amount of time looking at spermatozoa, as they're now called. Oddly enough, it was the milt he squeezed from a cod one day that inspired him to estimate, almost casually, just how many people might live on Earth.

Nobody then really had any idea; there were few censuses. Leeuwenhoek started with an estimate that around a million people lived in Holland. Using maps and a little spherical geometry, he calculated that the inhabited land area of the planet was 13,385 times as large as Holland. It was hard to imagine the whole planet being as densely peopled as Holland, which seemed crowded even then. Thus, Leeuwenhoek concluded triumphantly, there couldn't be more than 13.385 billion people on Earth—a small number indeed compared with the 150 billion sperm cells of a single codfish! This cheerful little calculation, writes population biologist Joel Cohen in his book How Many People Can the Earth Support?, may have been the first attempt to give a quantitative answer to a question that has become far more pressing now than it was in the 17th century. Most answers these days are far from cheerful.

Historians now estimate that in Leeuwenhoek's day there were only half a billion or so humans on Earth. After

rising very slowly for millennia, the number was just starting to take off. A century and a half later, when another scientist reported the discovery of human egg cells, the world's population had doubled to more than a billion. A century after that, around 1930, it had doubled again to two billion. The acceleration since then has been astounding. Before the 20th century, no human had lived through a doubling of the human population, but there are people alive today who have seen it triple. Sometime in late 2011, according to the UN Population Division, there will be seven billion of us.

And the explosion, though it is slowing, is far from over. Not only are people living longer, but so many women across the world are now in their children than she would have had a generation ago. By 2050 the total number could reach 10.5 billion, or it could stop at eight billion—the difference is about one child per woman. UN demographers consider the middle road their best estimate: They now project that the population may reach nine billion before 2050—in 2045. The eventual tally will depend on the choices individual couples make when they engage in that most intimate of human acts, the one Leeuwenhoek interrupted so carelessly for the sake of science.

With the population still growing by about 80 million each year, it's hard not to be alarmed. Right now on Earth, water tables are falling, soil is eroding, glaciers are melting, and fish stocks are vanishing. Close to a billion people go hungry each day. Decades from now, there will likely be two billion more mouths to feed, mostly in poor countries. There

will be billions more people wanting and deserving to boost themselves out of poverty. If they follow the path blazed by wealthy countries—clearing forests, burning coal and oil, freely scattering fertilizers and pesticides—they too will be stepping hard on the planet's natural resources. How exactly is this going to work?

THERE MAY BE SOME COMFORT in knowing that people have long been alarmed about population. From the beginning, says French demographer Hervé Le Bras, demography has been steeped in talk of the apocalypse. Some of the field's founding papers were written just a few years after Leeuwenhoek's discovery by Sir William Petty, a founder of the Royal Society. He estimated that world population would double six times by the Last Judgment, which was expected in about 2,000 years. At that point it would exceed 20 billion people—more, Petty thought, than the planet could feed. "And then, according to the prediction of the Scriptures, there must be wars, and great slaughter, &c.," he wrote.

As religious forecasts of the world's end receded, Le Bras argues, population growth itself provided an ersatz mechanism of apocalypse. "It crystallized the ancient fear, and perhaps the ancient hope, of the end of days," he writes. In 1798 Thomas Malthus, an English priest and economist, enunciated his general law of population: that it necessarily grows faster than the food supply, until war, disease, and famine arrive to reduce the number of people.

As it turned out, the last plagues great enough to put a dent in global population had already happened when Malthus wrote. World population hasn't fallen, historians think, since the Black Death of the 14th century.

In the two centuries after Malthus declared that population couldn't continue to soar, that's exactly what it did. The process started in what we now call the developed countries, which were then still developing. The spread of New World crops like corn and the potato, along with the discovery of chemical fertilizers, helped banish starvation in Europe. Growing cities remained cesspools of disease at first, but from the mid-19th century on, sewers began to channel human waste away from drinking water, which was then filtered and chlorinated; that dramatically reduced the spread of cholera and typhus.

Moreover in 1798, the same year that Malthus published his dyspeptic tract, his compatriot Edward Jenner described a vaccine for smallpox—the first and most important in a series of vaccines and antibiotics that, along with better nutrition and sanitation, would double life expectancy in the industrializing countries, from 35 years to 77 today. It would take a cranky person to see that trend as gloomy: "The development of medical science was the straw that broke the camel's back," wrote Stanford population biologist Paul Ehrlich in 1968.

Ehrlich's book, The Population Bomb, made him the most famous of modern Malthusians. In the 1970s, Ehrlich predicted, "hundreds of millions of people are going to starve to death," and it was too late to do anything about it.

“The cancer of population growth…must be cut out,” Ehrlich wrote, “by compulsion if voluntary methods fail.” The very future of the United States was at risk. In spite or perhaps because of such language, the book was a best seller, as Malthus’s had been. And this time too the bomb proved a dud. The green revolution—a combination of high-yield seeds, irrigation, pesticides, and fertilizers that enabled grain production to double—was already under way. Today many people are undernourished, but mass starvation is rare.

Ehrlich was right, though, that population would surge as medical science spared many lives. After World War II the developing countries got a sudden transfusion of preventive care, with the help of institutions like the World Health Organization and UNICEF. Penicillin, the smallpox vaccine, DDT (which, though later controversial, saved millions from dying of malaria)—all arrived at once. In India life expectancy went from 38 years in 1952 to 64 today; in China, from 41 to 73. Millions of people in developing countries who would have died in childhood survived to have children themselves. That’s why the population explosion spread around the planet: because a great many people were saved from dying.

And because, for a time, women kept giving birth at a high rate. In 18th-century Europe or early 20th-century Asia, when the average woman had six children, she was doing what it took to replace herself and her mate, because most of those children never reached adulthood. When child mortality declines, couples eventually have fewer children—

but that transition usually takes a generation at the very least. Today in developed countries, an average of 2.1 births per woman would maintain a steady population; in the developing world, “replacement fertility” is somewhat higher. In the time it takes for the birthrate to settle into that new balance with the death rate, population explodes.

Demographers call this evolution the demographic transition. All countries go through it in their own time. It’s a hallmark of human progress: In a country that has completed the transition, people have wrested from nature at least some control over death and birth. The global population explosion is an inevitable side effect, a huge one that some people are not sure our civilization can survive. But the growth rate was actually at its peak just as Ehrlich was sounding his alarm. By the early 1970s, fertility rates around the world had begun dropping faster than anyone had anticipated. Since then, the population growth rate has fallen by more than 40 percent.

THE FERTILITY DECLINE that is now sweeping the planet started at different times in different countries. France was one of the first. By the early 18th century, noblewomen at the French court were knowing carnal pleasures without bearing more than two children. They often relied on the same method Leeuwenhoek used for his studies: withdrawal, or coitus interruptus. Village parish records show the trend had spread to the peasantry by the late 18th century; by the end of the 19th, fertility in France had fallen to three children per

woman—without the help of modern contraceptives. The key innovation was conceptual, not contraceptive, says Gilles Pison of the National Institute for Demographic Studies in Paris. Until the Enlightenment, “the number of children you had, it was God who decided. People couldn’t fathom that it might be up to them.”

Other countries in the West eventually followed France’s lead. By the onset of World War II, fertility had fallen close to the replacement level in parts of Europe and the U.S. Then, after the surprising blip known as the baby boom, came the bust, again catching demographers off guard. They assumed some instinct would lead women to keep having enough children to ensure the survival of the species. Instead, in country after developed country, the fertility rate fell below replacement level. In the late 1990s in Europe it fell to 1.4. “The evidence I’m familiar with, which is anecdotal, is that women couldn’t care less about replacing the species,” Joel Cohen says.

The end of a baby boom can have two big economic effects on a country. The first is the “demographic dividend”—a blissful few decades when the boomers swell the labor force and the number of young and old dependents is relatively small, and there is thus a lot of money for other things. Then the second effect kicks in: The boomers start to retire. What had been considered the enduring demographic order is revealed to be a party that has to end. The sharpening American debate over Social Security and last year’s strikes in France over increasing the retirement age are responses to a problem that exists

throughout the developed world: how to support an aging population. “In 2050 will there be enough people working to pay for pensions?” asks Frans Willekens, director of the Netherlands Interdisciplinary Demographic Institute in The Hague. “The answer is no.”

In industrialized countries it took generations for fertility to fall to the replacement level or below. As that same transition takes place in the rest of the world, what has astonished demographers is how much faster it is happening there. Though its population continues to grow, China, home to a fifth of the world’s people, is already below replacement fertility and has been for nearly 20 years, thanks in part to the coercive one-child policy implemented in 1979; Chinese women, who were bearing an average of six children each as recently as 1965, are now having around 1.5. In Iran, with the support of the Islamic regime, fertility has fallen more than 70 percent since the early ’80s. In Catholic and democratic Brazil, women have reduced their fertility rate by half over the same quarter century. “We still don’t understand why fertility has gone down so fast in so many societies, so many cultures and religions. It’s just mind-boggling,” says Hania Zlotnik, director of the UN Population Division.

“At this moment, much as I want to say there’s still a problem of high fertility rates, it’s only about 16 percent of the world population, mostly in Africa,” says Zlotnik. South of the Sahara, fertility is still five children per woman; in Niger it is seven. But then, 17 of the countries in the region still have life expectancies of 50 or less; they have just

begun the demographic transition. In most of the world, however, family size has shrunk dramatically. The UN projects that the world will reach replacement fertility by 2030. “The population as a whole is on a path toward nonexplosion—which is good news,” Zlotnik says.

The bad news is that 2030 is two decades away and that the largest generation of adolescents in history will then be entering their childbearing years. Even if each of those women has only two children, population will coast upward under its own momentum for another quarter century. Is a train wreck in the offing, or will people then be able to live humanely and in a way that doesn’t destroy their environment? One thing is certain: Close to one in six of them will live in India.

I HAVE UNDERSTOOD *the population explosion intellectually for a long time. I came to understand it emotionally one stinking hot night in Delhi a couple of years ago… The temperature was well over 100, and the air was a haze of dust and smoke. The streets seemed alive with people. People eating, people washing, people sleeping. People visiting, arguing, and screaming. People thrusting their hands through the taxi window, begging. People defecating and urinating. People clinging to buses. People herding animals. People, people, people, people.*

—Paul Ehrlich

In 1966, when Ehrlich took that taxi ride, there were around half a billion Indians. There are 1.2 billion now. Delhi's population has increased even faster, to around 22 million, as people have flooded in from small towns and villages and crowded into sprawling shantytowns. Early last June in the stinking hot city, the summer monsoon had not yet arrived to wash the dust from the innumerable construction sites, which only added to the dust that blows in from the deserts of Rajasthan. On the new divided highways that funnel people into the unplanned city, oxcarts were heading the wrong way in the fast lane. Families of four cruised on motorbikes, the women's scarves flapping like vivid pennants, toddlers dangling from their arms. Families of a dozen or more sardined themselves into buzzing, bumblebee-colored auto rickshaws designed for two passengers. In the stalled traffic, amputees and wasted little children cried for alms. Delhi today is boomingly different from the city Ehrlich visited, and it is also very much the same.

At Lok Nayak Hospital, on the edge of the chaotic and densely peopled nest of lanes that is Old Delhi, a human tide flows through the entrance gate every morning and crowds inside on the lobby floor. "Who could see this and not be worried about the population of India?" a surgeon named Chandan Bortamuly asked one afternoon as he made his way toward his vasectomy clinic. "Population is our biggest problem." Removing the padlock from the clinic door, Bortamuly stepped into a small operating room. Inside, two men lay stretched out on examination tables,

their testicles poking up through holes in the green sheets. A ceiling fan pushed cool air from two window units around the room.

Bortamuly is on the front lines of a battle that has been going on in India for nearly 60 years. In 1952, just five years after it gained independence from Britain, India became the first country to establish a policy for population control. Since then the government has repeatedly set ambitious goals—and repeatedly missed them by a mile. A national policy adopted in 2000 called for the country to reach the replacement fertility of 2.1 by 2010. That won't happen for at least another decade. In the UN's medium projection, India's population will rise to just over 1.6 billion people by 2050. "What's inevitable is that India is going to exceed the population of China by 2030," says A. R. Nanda, former head of the Population Foundation of India, an advocacy group. "Nothing less than a huge catastrophe, nuclear or otherwise, can change that."

Sterilization is the dominant form of birth control in India today, and the vast majority of the procedures are performed on women. The government is trying to change that; a no-scalpel vasectomy costs far less and is easier on a man than a tubal ligation is on a woman. In the operating theater Bortamuly worked quickly. "They say the needle pricks like an ant bite," he explained, when the first patient flinched at the local anesthetic. "After that it's basically painless, bloodless surgery." Using the pointed tip of a forceps, Bortamuly made a tiny hole in the skin of the scrotum and pulled out an oxbow of white, stringy vas

deferens—the sperm conduit from the patient's right testicle. He tied off both ends of the oxbow with fine black thread, snipped them, and pushed them back under the skin. In less than seven minutes—a nurse timed him—the patient was walking out without so much as a Band-Aid. The government will pay him an incentive fee of 1,100 rupees (around $25), a week's wages for a laborer.

The Indian government tried once before to push vasectomies, in the 1970s, when anxiety about the population bomb was at its height. Prime Minister Indira Gandhi and her son Sanjay used state-of-emergency powers to force a dramatic increase in sterilizations. From 1976 to 1977 the number of operations tripled, to more than eight million. Over six million of those were vasectomies. Family planning workers were pressured to meet quotas; in a few states, sterilization became a condition for receiving new housing or other government benefits. In some cases the police simply rounded up poor people and hauled them to sterilization camps.

The excesses gave the whole concept of family planning a bad name. "Successive governments refused to touch the subject," says Shailaja Chandra, former head of the National Population Stabilisation Fund (NPSF). Yet fertility in India has dropped anyway, though not as fast as in China, where it was nose-diving even before the draconian one-child policy took effect. The national average in India is now 2.6 children per woman, less than half what it was when Ehrlich visited. The southern half of the country and a few states in the northern half are already at replacement

fertility or below.

In Kerala, on the southwest coast, investments in health and education helped fertility fall to 1.7. The key, demographers there say, is the female literacy rate: At around 90 percent, it's easily the highest in India. Girls who go to school start having children later than ones who don't. They are more open to contraception and more likely to understand their options.

SO FAR THIS APPROACH, held up as a model internationally, has not caught on in the poor states of northern India—in the "Hindi belt" that stretches across the country just south of Delhi. Nearly half of India's population growth is occurring in Rajasthan, Madhya Pradesh, Bihar, and Uttar Pradesh, where fertility rates still hover between three and four children per woman. More than half the women in the Hindi belt are illiterate, and many marry well before reaching the legal age of 18. They gain social status by bearing children—and usually don't stop until they have at least one son.

As an alternative to the Kerala model, some point to the southern state of Andhra Pradesh, where sterilization "camps"—temporary operating rooms often set up in schools—were introduced during the '70s and where sterilization rates have remained high as improved hospitals have replaced the camps. In a single decade beginning in the early 1990s, the fertility rate fell from around three to less than two. Unlike in Kerala, half of all women in Andhra Pradesh remain illiterate.

Amarjit Singh, the current executive director of the NPSF, calculates that if the four biggest states of the Hindi belt had followed the Andhra Pradesh model, they would have avoided 40 million births—and considerable suffering. "Because 40 million were born, 2.5 million children died," Singh says. He thinks if all India were to adopt high-quality programs to encourage sterilizations, in hospitals rather than camps, it could have 1.4 billion people in 2050 instead of 1.6 billion.

Critics of the Andhra Pradesh model, such as the Population Foundation's Nanda, say Indians need better health care, particularly in rural areas. They are against numerical targets that pressure government workers to sterilize people or cash incentives that distort a couple's choice of family size. "It's a private decision," Nanda says.

In Indian cities today, many couples are making the same choice as their counterparts in Europe or America. Sonalde Desai, a senior fellow at New Delhi's National Council of Applied Economic Research, introduced me to five working women in Delhi who were spending most of their salaries on private-school fees and after-school tutors; each had one or two children and was not planning to have more. In a nationwide survey of 41,554 households, Desai's team identified a small but growing vanguard of urban one-child families. "We were totally blown away at the emphasis parents were placing on their children," she says. "It suddenly makes you understand—that is why fertility is going down." Indian children on average are much better educated than their parents.

That's less true in the countryside. With Desai's team I went to Palanpur, a village in Uttar Pradesh—a Hindi-belt state with as many people as Brazil. Walking into the village we passed a cell phone tower but also rivulets of raw sewage running along the lanes of small brick houses. Under a mango tree, the keeper of the grove said he saw no reason to educate his three daughters. Under a neem tree in the center of the village, I asked a dozen farmers what would improve their lives most. "If we could get a little money, that would be wonderful," one joked.

The goal in India should not be reducing fertility or population, Almas Ali of the Population Foundation told me when I spoke to him a few days later. "The goal should be to make the villages livable," he said. "Whenever we talk of population in India, even today, what comes to our mind is the increasing numbers. And the numbers are looked at with fright. This phobia has penetrated the mind-set so much that all the focus is on reducing the number. The focus on people has been pushed to the background."

It was a four-hour drive back to Delhi from Palanpur, through the gathering night of a Sunday. We sat in traffic in one market town after another, each one hopping with activity that sometimes engulfed the car. As we came down a viaduct into Moradabad, I saw a man pushing a cart up the steep hill, piled with a load so large it blocked his view. I thought of Ehrlich's epiphany on his cab ride all those decades ago. People, people, people, people—yes. But also an overwhelming sense of energy, of striving, of aspiration.

THE ANNUAL meeting of the Population Association of America (PAA) is one of the premier gatherings of the world's demographers. Last April the global population explosion was not on the agenda. "The problem has become a bit passé," Hervé Le Bras says. Demographers are generally confident that by the second half of this century we will be ending one unique era in history—the population explosion—and entering another, in which population will level out or even fall.

But will there be too many of us? At the PAA meeting, in the Dallas Hyatt Regency, I learned that the current population of the planet could fit into the state of Texas, if Texas were settled as densely as New York City. The comparison made me start thinking like Leeuwenhoek. If in 2045 there are nine billion people living on the six habitable continents, the world population density will be a little more than half that of France today. France is not usually considered a hellish place. Will the world be hellish then?

Some parts of it may well be; some parts of it are hellish today. There are now 21 cities with populations larger than ten million, and by 2050 there will be many more. Delhi adds hundreds of thousands of migrants each year, and those people arrive to find that "no plans have been made for water, sewage, or habitation," says Shailaja Chandra. Dhaka in Bangladesh and Kinshasa in the Democratic Republic of the Congo are 40 times larger today than they were in 1950. Their slums are filled with desperately poor

people who have fled worse poverty in the countryside.

Whole countries today face population pressures that seem as insurmountable to us as India's did to Ehrlich in 1966. Bangladesh is among the most densely populated countries in the world and one of the most immediately threatened by climate change; rising seas could displace tens of millions of Bangladeshis. Rwanda is an equally alarming case. In his book Collapse, Jared Diamond argued that the genocidal massacre of some 800,000 Rwandans in 1994 was the result of several factors, not only ethnic hatred but also overpopulation—too many farmers dividing the same amount of land into increasingly small pieces that became inadequate to support a farmer's family. "Malthus's worst-case scenario may sometimes be realized," Diamond concluded.

Many people are justifiably worried that Malthus will finally be proved right on a global scale—that the planet won't be able to feed nine billion people. Lester Brown, founder of Worldwatch Institute and now head of the Earth Policy Institute in Washington, believes food shortages could cause a collapse of global civilization. Human beings are living off natural capital, Brown argues, eroding soil and depleting groundwater faster than they can be replenished. All of that will soon be cramping food production. Brown's Plan B to save civilization would put the whole world on a wartime footing, like the U.S. after Pearl Harbor, to stabilize climate and repair the ecological damage. "Filling the family planning gap may be the most urgent item on the global agenda," he writes, so if we don't hold the world's

population to eight billion by reducing fertility, the death rate may increase instead.

Eight billion corresponds to the UN's lowest projection for 2050. In that optimistic scenario, Bangladesh has a fertility rate of 1.35 in 2050, but it still has 25 million more people than it does today. Rwanda's fertility rate also falls below the replacement level, but its population still rises to well over twice what it was before the genocide. If that's the optimistic scenario, one might argue, the future is indeed bleak.

But one can also draw a different conclusion—that fixating on population numbers is not the best way to confront the future. People packed into slums need help, but the problem that needs solving is poverty and lack of infrastructure, not overpopulation. Giving every woman access to family planning services is a good idea—"the one strategy that can make the biggest difference to women's lives," Chandra calls it. But the most aggressive population control program imaginable will not save Bangladesh from sea level rise, Rwanda from another genocide, or all of us from our enormous environmental problems.

Global warming is a good example. Carbon emissions from fossil fuels are growing fastest in China, thanks to its prolonged economic boom, but fertility there is already below replacement; not much more can be done to control population. Where population is growing fastest, in sub-Saharan Africa, emissions per person are only a few percent of what they are in the U.S.—so population control

would have little effect on climate. Brian O'Neill of the National Center for Atmospheric Research has calculated that if the population were to reach 7.4 billion in 2050 instead of 8.9 billion, it would reduce emissions by 15 percent. "Those who say the whole problem is population are wrong," Joel Cohen says. "It's not even the dominant factor." To stop global warming we'll have to switch from fossil fuels to alternative energy—regardless of how big the population gets.

THE NUMBER OF PEOPLE DOES MATTER, of course. But how people consume resources matters a lot more. Some of us leave much bigger footprints than others. The central challenge for the future of people and the planet is how to raise more of us out of poverty—the slum dwellers in Delhi, the subsistence farmers in Rwanda—while reducing the impact each of us has on the planet.

The World Bank has predicted that by 2030 more than a billion people in the developing world will belong to the "global middle class," up from just 400 million in 2005. That's a good thing. But it will be a hard thing for the planet if those people are eating meat and driving gasoline-powered cars at the same rate as Americans now do. It's too late to keep the new middle class of 2030 from being born; it's not too late to change how they and the rest of us will produce and consume food and energy. "Eating less meat seems more reasonable to me than saying, 'Have fewer children!'" Le Bras says.

How many people can the Earth support? Cohen spent years reviewing all the research, from Leeuwenhoek on. "I wrote the book thinking I would answer the question," he says. "I found out it's unanswerable in the present state of knowledge." What he found instead was an enormous range of "political numbers, intended to persuade people" one way or the other.

For centuries population pessimists have hurled apocalyptic warnings at the congenital optimists, who believe in their bones that humanity will find ways to cope and even improve its lot. History, on the whole, has so far favored the optimists, but history is no certain guide to the future. Neither is science. It cannot predict the outcome of People v. Planet, because all the facts of the case—how many of us there will be and how we will live—depend on choices we have yet to make and ideas we have yet to have. We may, for example, says Cohen, "see to it that all children are nourished well enough to learn in school and are educated well enough to solve the problems they will face as adults." That would change the future significantly.

The debate was present at the creation of population alarmism, in the person of Rev. Thomas Malthus himself. Toward the end of the book in which he formulated the iron law by which unchecked population growth leads to famine, he declared that law a good thing: It gets us off our duffs. It leads us to conquer the world. Man, Malthus wrote, and he must have meant woman too, is "inert, sluggish, and averse from labour, unless compelled by necessity." But necessity, he added, gives hope:

“The exertions that men find it necessary to make, in order to support themselves or families, frequently awaken faculties that might otherwise have lain for ever dormant, and it has been commonly remarked that new and extraordinary situations generally create minds adequate to grapple with the difficulties in which they are involved.”

Seven billion of us now, nine billion in 2045. Let’s hope that Malthus was right about our ingenuity.

Chapter 2: Enter the Anthropocene Age of Man

BY ELIZABETH KOLBERT

Elizabeth Kolbert is the author of Field Notes From a Catastrophe, *a book about climate change. The photographers whose work appears here share a passion for documenting human impacts on the planet.*

THE PATH LEADS UP A HILL, across a fast-moving stream, back across the stream, and then past the carcass of a sheep. In my view it's raining, but here in the Southern Uplands of Scotland, I'm told, this counts as only a light drizzle, or smirr. Just beyond the final switchback, there's a waterfall, half shrouded in mist, and an outcropping of jagged rock. The rock has bands that run vertically, like a layer cake that's been tipped on its side. My guide, Jan Zalasiewicz, a British stratigrapher, points to a wide stripe of gray. "Bad things happened in here," he says.

The stripe was laid down some 445 million years ago, as sediments slowly piled up on the bottom of an ancient ocean. In those days life was still confined mostly to the water, and it was undergoing a crisis. Between one edge of the three-foot-thick gray band and the other, some 80 percent of marine species died out, many of them the sorts of creatures, like graptolites, that no longer exist. The extinction event, known as the end-Ordovician, was one of

the five biggest of the past half billion years. It coincided with extreme changes in climate, in global sea levels, and in ocean chemistry—all caused, perhaps, by a super-continent drifting over the South Pole.

Stratigraphers like Zalasiewicz are, as a rule, hard to impress. Their job is to piece together Earth's history from clues that can be coaxed out of layers of rock millions of years after the fact. They take the long view—the extremely long view—of events, only the most violent of which are likely to leave behind clear, lasting signals. It's those events that mark the crucial episodes in the planet's 4.5-billion-year story, the turning points that divide it into comprehensible chapters.

So it's disconcerting to learn that many stratigraphers have come to believe that *we* are such an event—that human beings have so altered the planet in just the past century or two that we've ushered in a new epoch: the Anthropocene. Standing in the smirr, I ask Zalasiewicz what he thinks this epoch will look like to the geologists of the distant future, whoever or whatever they may be. Will the transition be a moderate one, like dozens of others that appear in the record, or will it show up as a sharp band in which very bad things happened—like the mass extinction at the end of the *Ordovician?*

That, Zalasiewicz says, is what we are in the process of determining.

THE WORD "ANTHROPOCENE" was coined by Dutch chemist Paul

Crutzen about a decade ago. One day Crutzen, who shared a Nobel Prize for discovering the effects of ozone-depleting compounds, was sitting at a scientific conference. The conference chairman kept referring to the Holocene, the epoch that began at the end of the last ice age, 11,500 years ago, and that—officially, at least—continues to this day.

"'Let's stop it,'" Crutzen recalls blurting out. "'We are no longer in the Holocene. We are in the Anthropocene.' Well, it was quiet in the room for a while." When the group took a coffee break, the Anthropocene was the main topic of conversation. Someone suggested that Crutzen copyright the word.

Way back in the 1870s, an Italian geologist named Antonio Stoppani proposed that people had introduced a new era, which he labeled the anthropozoic. Stoppani's proposal was ignored; other scientists found it unscientific. The Anthropocene, by contrast, struck a chord. Human impacts on the world have become a lot more obvious since Stoppani's day, in part because the size of the population has roughly quadrupled, to nearly seven billion. "The pattern of human population growth in the twentieth century was more bacterial than primate," biologist E. O. Wilson has written. Wilson calculates that human biomass is already a hundred times larger than that of any other large animal species that has ever walked the Earth.

In 2002, when Crutzen wrote up the Anthropocene idea in the journal *Nature,* the concept was immediately picked up by researchers working in a wide range of disciplines.

Soon it began to appear regularly in the scientific press. “Global Analysis of River Systems: From Earth System Controls to Anthropocene Syndromes” ran the title of one 2003 paper. “Soils and Sediments in the Anthropocene” was the headline of another, published in 2004.

At first most of the scientists using the new geologic term were not geologists. Zalasiewicz, who is one, found the discussions intriguing. “I noticed that Crutzen’s term was appearing in the serious literature, without quotation marks and without a sense of irony,” he says. In 2007 Zalasiewicz was serving as chairman of the Geological Society of London’s Stratigraphy Commission. At a meeting he decided to ask his fellow stratigraphers what they thought of the Anthropocene. Twenty-one of 22 thought the concept had merit.

The group agreed to look at it as a formal problem in geology. Would the Anthropocene satisfy the criteria used for naming a new epoch? In geologic parlance, epochs are relatively short time spans, though they can extend for tens of millions of years. (Periods, such as the Ordovician and the Cretaceous, last much longer, and eras, like the Mesozoic, longer still.) The boundaries between epochs are defined by changes preserved in sedimentary rocks—the emergence of one type of commonly fossilized organism, say, or the disappearance of another.

The rock record of the present doesn’t exist yet, of course. So the question was: When it does, will human impacts show up as “stratigraphically significant”? The answer, Zalasiewicz’s group decided, is yes—though not

necessarily for the reasons you'd expect.

PROBABLY THE MOST OBVIOUS way humans are altering the planet is by building cities, which are essentially vast stretches of man-made materials—steel, glass, concrete, and brick. But it turns out most cities are not good candidates for long-term preservation, for the simple reason that they're built on land, and on land the forces of erosion tend to win out over those of sedimentation. From a geologic perspective, the most plainly visible human effects on the landscape today "may in some ways be the most transient," Zalasiewicz has observed.

Humans have also transformed the world through farming; something like 38 percent of the planet's ice-free land is now devoted to agriculture. Here again, some of the effects that seem most significant today will leave behind only subtle traces at best.

Fertilizer factories, for example, now fix more nitrogen from the air, converting it to a biologically usable form, than all the plants and microbes on land; the runoff from fertilized fields is triggering life-throttling blooms of algae at river mouths all over the world. But this global perturbation of the nitrogen cycle will be hard to detect, because synthesized nitrogen is just like its natural equivalent. Future geologists are more likely to grasp the scale of 21st-century industrial agriculture from the pollen record—from the monochrome stretches of corn, wheat, and soy pollen that will have replaced the varied record left behind by rain forests or

prairies.

The leveling of the world's forests will send at least two coded signals to future stratigraphers, though deciphering the first may be tricky. Massive amounts of soil eroding off denuded land are increasing sedimentation in some parts of the world—but at the same time the dams we've built on most of the world's major rivers are holding back sediment that would otherwise be washed to sea. The second signal of deforestation should come through clearer. Loss of forest habitat is a major cause of extinctions, which are now happening at a rate hundreds or even thousands of times higher than during most of the past half billion years. If current trends continue, the rate may soon be tens of thousands of times higher.

Probably the most significant change, from a geologic perspective, is one that's invisible to us—the change in the composition of the atmosphere. Carbon dioxide emissions are colorless, odorless, and in an immediate sense, harmless. But their warming effects could easily push global temperatures to levels that have not been seen for millions of years. Some plants and animals are already shifting their ranges toward the Poles, and those shifts will leave traces in the fossil record. Some species will not survive the warming at all. Meanwhile rising temperatures could eventually raise sea levels 20 feet or more.

Long after our cars, cities, and factories have turned to dust, the consequences of burning billions of tons' worth of coal and oil are likely to be clearly discernible. As carbon dioxide warms the planet, it also seeps into the oceans and

acidifies them. Sometime this century they may become acidified to the point that corals can no longer construct reefs, which would register in the geologic record as a "reef gap." Reef gaps have marked each of the past five major mass extinctions. The most recent one, which is believed to have been caused by the impact of an asteroid, took place 65 million years ago, at the end of the Cretaceous period; it eliminated not just the dinosaurs, but also the plesiosaurs, pterosaurs, and ammonites. The scale of what's happening now to the oceans is, by many accounts, unmatched since then. To future geologists, Zalasiewicz says, our impact may look as sudden and profound as that of an asteroid.

IF WE HAVE INDEED entered a new epoch, then when exactly did it begin? When did human impacts rise to the level of geologic significance?

William Ruddiman, a paleoclimatologist at the University of Virginia, has proposed that the invention of agriculture some 8,000 years ago, and the deforestation that resulted, led to an increase in atmospheric CO_2 just large enough to stave off what otherwise would have been the start of a new ice age; in his view, humans have been the dominant force on the planet practically since the start of the Holocene. Crutzen has suggested that the Anthropocene began in the late 18th century, when, ice cores show, carbon dioxide levels began what has since proved to be an uninterrupted rise. Other scientists put the beginning of the new epoch in the middle of the 20th century, when the rates of both

population growth and consumption accelerated rapidly.

Zalasiewicz now heads a working group of the International Commission on Stratigraphy (ICS) that is tasked with officially determining whether the Anthropocene deserves to be incorporated into the geologic timescale. A final decision will require votes by both the ICS and its parent organization, the International Union of Geological Sciences. The process is likely to take years. As it drags on, the decision may well become easier. Some scientists argue that we've not yet reached the start of the Anthropocene—not because we haven't had a dramatic impact on the planet, but because the next several decades are likely to prove even more stratigraphically significant than the past few centuries. "Do we decide the Anthropocene's here, or do we wait 20 years and things will be even worse?" says Mark Williams, a geologist and colleague of Zalasiewicz's at the University of Leicester in England.

Crutzen, who started the debate, thinks its real value won't lie in revisions to geology textbooks. His purpose is broader: He wants to focus our attention on the consequences of our collective action—and on how we might still avert the worst. "What I hope," he says, "is that the term 'Anthropocene' will be a warning to the world."

Chapter 3: The Acid Sea

BY ELIZABETH KOLBERT

Elizabeth Kolbert wrote last month about the idea that human impacts on the planet will long outlive us. David Liittschwager's photos of life in one cubic foot of soil or sea appeared in February 2010.

CASTELLO ARAGONESE IS A TINY ISLAND that rises straight out of the Tyrrhenian Sea like a tower. Seventeen miles west of Naples, it can be reached from the somewhat larger island of Ischia via a long, narrow stone bridge. The tourists who visit Castello Aragonese come to see what life was like in the past. They climb—or better yet, take the elevator—up to a massive castle, which houses a display of medieval torture instruments. The scientists who visit the island, by contrast, come to see what life will be like in the future.

Owing to a quirk of geology, the sea around Castello Aragonese provides a window onto the oceans of 2050 and beyond. Bubbles of CO_2 rise from volcanic vents on the seafloor and dissolve to form carbonic acid. Carbonic acid is relatively weak; people drink it all the time in carbonated beverages. But if enough of it forms, it makes seawater corrosive. "When you get to the extremely high CO_2, almost nothing can tolerate that," Jason Hall-Spencer, a marine biologist from Britain's University of Plymouth, explains. Castello Aragonese offers a natural analogue for

an unnatural process: The acidification that has taken place off its shore is occurring more gradually across the world's oceans, as they absorb more and more of the carbon dioxide that's coming from tailpipes and smokestacks.

Hall-Spencer has been studying the sea around the island for the past eight years, carefully measuring the properties of the water and tracking the fish and corals and mollusks that live and, in some cases, dissolve there. On a chilly winter's day I went swimming with him and with Maria Cristina Buia, a scientist at Italy's Anton Dohrn Zoological Station, to see the effects of acidification up close. We anchored our boat about 50 yards from the southern shore of Castello Aragonese. Even before we got into the water, some impacts were evident. Clumps of barnacles formed a whitish band at the base of the island's wave-battered cliffs. "Barnacles are really tough," Hall-Spencer observed. In the areas where the water was most acidified, though, they were missing.

We all dived in. Buia was carrying a knife. She pried some unlucky limpets from a rock. Searching for food, they had wandered into water that was too caustic for them. Their shells were so thin they were almost transparent. Bubbles of carbon dioxide streamed up from the seafloor like beads of quicksilver. We swam on. Beds of sea grass waved beneath us. The grass was a vivid green; the tiny organisms that usually coat the blades, dulling their color, were all missing. Sea urchins, commonplace away from the vents, were also absent; they can't tolerate even moderately acidified water. Swarms of nearly transparent

jellyfish floated by. “Watch out,” Hall-Spencer warned. “They sting.”

Jellyfish, sea grass, and algae—not much else lives near the densest concentration of vents at Castello Aragonese. Even a few hundred yards away, many native species can’t survive. The water there is about as acidified as the oceans as a whole are forecast to be by 2100. “Normally in a polluted harbor you’ve got just a few species that are weedlike and able to cope with widely fluctuating conditions,” Hall-Spencer said once we were back on the boat. “Well, it’s like that when you ramp up CO_2.”

SINCE THE START of the industrial revolution, enough fossil fuels —coal, oil, and natural gas—have been burned and enough forests cut down to emit more than 500 billion tons of CO_2. As is well known, the atmosphere has a higher concentration of CO_2 today than at any point in the past 800,000 years and probably a lot longer.

What is less well known is how carbon emissions are changing the oceans too. The air and the water constantly exchange gases, so a portion of anything emitted into the atmosphere eventually ends up in the sea. Winds quickly mix it into the top few hundred feet, and over centuries currents spread it through the ocean depths. In the 1990s an international team of scientists undertook a massive research project that involved collecting and analyzing more than 77,000 seawater samples from different depths and

locations around the world. The work took 15 years. It showed that the oceans have absorbed 30 percent of the CO_2 released by humans over the past two centuries. They continue to absorb roughly a million tons every hour.

For life on land this process is a boon; every ton of CO_2 the oceans remove from the atmosphere is a ton that's not contributing to global warming. But for life in the sea the picture looks different. The head of the National Oceanic and Atmospheric Administration, Jane Lubchenco, a marine ecologist, has called ocean acidification global warming's "equally evil twin."

The pH scale, which measures acidity in terms of the concentration of hydrogen ions, runs from zero to 14. At the low end of the scale are strong acids, such as hydrochloric acid, that release hydrogen readily (more readily than carbonic acid does). At the high end are strong bases such as lye. Pure, distilled water has a pH of 7, which is neutral. Seawater should be slightly basic, with a pH around 8.2 near the sea surface. So far CO_2 emissions have reduced the pH there by about 0.1. Like the Richter scale, the pH scale is logarithmic, so even small numerical changes represent large effects. A pH drop of 0.1 means the water has become 30 percent more acidic. If present trends continue, surface pH will drop to around 7.8 by 2100. At that point the water will be 150 percent more acidic than it was in 1800.

The acidification that has occurred so far is probably irreversible. Although in theory it's possible to add

chemicals to the sea to counter the effects of the extra CO_2, as a practical matter, the volumes involved would be staggering; it would take at least two tons of lime, for example, to offset a single ton of carbon dioxide, and the world now emits more than 30 billion tons of CO_2 each year. Meanwhile, natural processes that could counter acidification—such as the weathering of rocks on land—operate far too slowly to make a difference on a human timescale. Even if CO_2 emissions were somehow to cease today, it would take tens of thousands of years for ocean chemistry to return to its preindustrial condition.

Acidification has myriad effects. By favoring some marine microbes over others, it is likely to alter the availability of key nutrients like iron and nitrogen. For similar reasons it may let more sunlight penetrate the sea surface. By changing the basic chemistry of seawater, acidification is also expected to reduce the water's ability to absorb and muffle low-frequency sound by up to 40 percent, making some parts of the ocean noisier. Finally, acidification interferes with reproduction in some species and with the ability of others—the so-called calcifiers—to form shells and stony skeletons of calcium carbonate. These last effects are the best documented ones, but whether they will prove the most significant in the long run is unclear.

In 2008 a group of more than 150 leading researchers issued a declaration stating that they were "deeply concerned by recent, rapid changes in ocean chemistry,"

which could within decades “severely affect marine organisms, food webs, biodiversity, and fisheries.” Warm-water coral reefs are the prime worry. But because carbon dioxide dissolves more readily in cold water, the impact may actually show up first closer to the Poles. Scientists have already documented significant effects on pteropods—tiny swimming snails that are an important food for fish, whales, and birds in both the Arctic and the Antarctic. Experiments show that pteropod shells grow more slowly in acidified seawater.

Will organisms be able to adapt to the new ocean chemistry? The evidence from Castello Aragonese is not encouraging. The volcanic vents have been pouring CO_2 into the water for at least a thousand years, Hall-Spencer told me when I visited. But the area where the pH is 7.8—the level that may be reached oceanwide by the end of the century—is missing nearly a third of the species that live nearby, outside the vent system. Those species have had “generations on generations to adapt to these conditions,” Hall-Spencer said, “yet they’re not there.

“Because it’s so important, we humans put a lot of energy into making sure that the pH of our blood is constant,” he went on. “But some of these lower organisms, they don’t have the physiology to do that. They’ve just got to tolerate what’s happening outside. And so they get pushed beyond their limits.”

FIFTY MILES OFF THE COAST of Australia and half a world away

from Castello Aragonese lies the equally tiny One Tree Island. One Tree, which actually has several hundred trees, is shaped like a boomerang, with two arms that stretch out into the Coral Sea. In the crook of the boomerang there's a small research station run by the University of Sydney. As it happened, just as I arrived one spectacular summer afternoon, an enormous loggerhead turtle heaved herself up onto the beach in front of the lab buildings. The island's entire human population—11 people, not including me—gathered around to watch.

One Tree Island is part of the Great Barrier Reef, the world's largest reef complex, which stretches for more than 1,400 miles. The entire island is composed of bits of coral rubble, ranging from marble to basketball size, that began piling up after a peculiarly violent storm about 4,000 years ago. Even today, the island has nothing that could really be called dirt. The trees seem to rise up directly out of the rubble like flagpoles.

When scientists first started visiting the island in the 1960s, they posed questions like, How do reefs grow? Nowadays the questions are more urgent. "Something like 25 percent of all species in the oceans spend at least part of their life in coral reef systems," Ken Caldeira, an expert on ocean acidification at the Carnegie Institution, said one evening before heading out to collect water samples on the reef. "Corals build the architecture of the ecosystem, and it's pretty clear if they go, the whole ecosystem goes."

Coral reefs are already threatened by a wide array of forces. Rising water temperatures are producing more

frequent “bleaching” events, when corals turn a stark white and often die. Overfishing removes grazers that keep reefs from being overgrown with algae. Agricultural runoff fertilizes algae, further upsetting reef ecology. In the Caribbean some formerly abundant coral species have been devastated by an infection that leaves behind a white band of dead tissue. Probably owing to all these factors, coral cover in the Caribbean declined by around 80 percent between 1977 and 2001.

Ocean acidification adds yet another threat, one that may be less immediate but ultimately more devastating to hard, reef-building corals. It undermines their basic, ancient structure—the stony skeleton that’s secreted by millions upon millions of coral polyps over thousands of years.

Coral polyps are tiny animals that form a thin layer of living tissue on the surface of a reef. They’re shaped a bit like flowers, with six or more tentacles that capture food and feed it to a central mouth. (Many corals actually get most of their food from algae that live and photosynthesize inside them; when corals bleach, it’s because stress has prompted the polyps to expel those dark symbionts.) Each polyp surrounds itself with a protective, cup-shaped exoskeleton of calcium carbonate that contributes to the collective skeleton of the whole colony.

To make calcium carbonate, corals need two ingredients: calcium ions and carbonate ions. Acids react with carbonate ions, in effect tying them up. So as atmospheric CO_2 levels rise, carbonate ions become

scarcer in the water, and corals have to expend more energy to collect them. Under lab conditions coral skeleton growth has been shown to decline pretty much linearly as the carbonate concentration drops off.

Slow growth may not matter much in the lab. Out in the ocean, though, reefs are constantly being picked at by other organisms, both large and small. (When I went snorkeling off One Tree Island, I could hear parrotfish chomping away at the reef.) “A reef is like a city,” said Ove Hoegh-Guldberg, who used to direct the One Tree Island Research Station and now heads the Global Change Institute at Australia’s University of Queensland. “You’ve got construction firms and you’ve got demolition firms. By restricting the building materials that go to the construction firms, you tip the balance toward destruction, which is going on all the time, even on a healthy reef. In the end you wind up with a city that destroys itself.”

By comparing measurements made in the 1970s with those taken more recently, Caldeira’s team found that at one location on the northern tip of the reef, calcification had declined by 40 percent. (The team was at One Tree to repeat this study at the southern tip of the reef.) A different team using a different method has found that the growth of Porites corals, which form massive, boulderlike clumps, declined 14 percent on the Great Barrier Reef between 1990 and 2005.

OCEAN ACIDIFICATION seems to affect corals’ ability to produce

new colonies as well. Corals can, in effect, clone themselves, and an entire colony is likely to be made up of genetically identical polyps. But once a year, in summer, many species of coral also engage in “mass spawning,” a kind of synchronized group sex. Each polyp produces a beadlike pink sac that contains both eggs and sperm. On the night of the spawning all the polyps release their sacs into the water. So many sacs are bobbing around that the waves seem to be covered in a veil of mauve.

Selina Ward, a researcher at the University of Queensland, has been studying coral reproduction on Heron Island, about ten miles west of One Tree, for the past 16 years. I met up with her just a few hours before the annual spawning event. She was keeping tabs on a dozen tanks of gravid corals, like an obstetrician making the rounds of a maternity ward. As soon as the corals released their pink sacs, she was planning to scoop them up and subject them to different levels of acidification. Her results so far suggest that lower pH leads to declines in fertilization, in larval development, and also in settlement—the stage at which the coral larvae drop out of the water column, attach themselves to something solid, and start producing new colonies. “And if any of those steps doesn’t work, you’re not going to get replacement corals coming into your system,” Ward said.

The reefs that corals maintain are crucial to an incredible diversity of organisms. Somewhere between one and nine million marine species live on or around coral reefs. These include not just the fancifully colored fish and

enormous turtles that people visit reefs to see, but also sea squirts and shrimps, anemones and clams, sea cucumbers and worms—the list goes on and on. The nooks and crevices on a reef provide homes for many species, which in turn provide resources for many others.

Once a reef can no longer grow fast enough to keep up with erosion, this community will crumble. “Coral reefs will lose their ecological functionality,” Jack Silverman, a member of Caldeira’s team at One Tree, told me. “They won’t be able to maintain their framework. And if you don’t have a building, where are the tenants going to live?” That moment could come by 2050. Under the business-as-usual emissions scenario, CO_2 concentrations in the atmosphere will be roughly double what they were in preindustrial times. Many experiments suggest that coral reefs will then start to disintegrate.

“Under business as usual, by mid-century things are looking rather grim,” Caldeira said. He paused for a moment. “I mean, they’re looking grim already.”

CORALS, OF COURSE, are just one kind of calcifier. There are thousands of others. Crustaceans like barnacles are calcifiers, and so are echinoderms like sea stars and sea urchins and mollusks like clams and oysters. Coralline algae—minute organisms that produce what looks like a coating of pink or lilac paint—are also calcifiers. Their calcium carbonate secretions help cement coral reefs together, but they’re also found elsewhere—on sea grass

at Castello Aragonese, for instance. It was their absence from the grass near the volcanic vents that made it look so green.

The seas are filled with one-celled calcifying plants called coccolithophores, whose seasonal blooms turn thousands of square miles of ocean a milky hue. Many species of planktonic foraminifera—also one-celled—are calcifiers; their dead shells drift down to the ocean floor in what's been described as a never ending rain. Calcifiers are so plentiful they've changed the Earth's geology. England's White Cliffs of Dover, for example, are the remains of countless ancient calcifiers that piled up during the Cretaceous period.

Acidification makes all calcifiers work harder, though some seem better able to cope. In experiments on 18 species belonging to different taxonomic groups, researchers at the Woods Hole Oceanographic Institution found that while a majority calcified less when CO_2 was high, some calcified more. One species—blue mussels—showed no change, no matter how acidified the water.

"Organisms make choices," explained Ulf Riebesell, a biological oceanographer at the Leibniz Institute of Marine Sciences in Kiel, Germany. "They sense the change in their environment, and some of them have the ability to compensate. They just have to invest more energy into calcification. They choose, 'OK, I'll invest less in reproduction' or 'I'll invest less in growth.'" What drives such choices, and whether they're viable over the long term, is

not known; most studies so far have been performed on creatures living for a brief time in tanks, without other species that might compete with them. “If I invest less in growth or in reproduction,” Riebesell went on, “does it mean that somebody else who does not have to make this choice, because they are not calcifying, will win out and take my spot?”

Meanwhile, scientists are just beginning to explore the way that ocean acidification will affect more-complex organisms such as fish and marine mammals. Changes at the bottom of the marine food web—to shell-forming pteropods, say, or coccolithophores—will inevitably affect the animals higher up. But altering oceanic pH is also likely to have a direct impact on their physiology. Researchers in Australia have found, for example, that young clownfish—the real-life versions of Nemo—can’t find their way to suitable habitat when CO_2 is elevated. Apparently the acidified water impairs their sense of smell.

DURING THE LONG HISTORY of life on Earth, atmospheric carbon dioxide levels have often been higher than they are today. But only very rarely—if ever—have they risen as quickly as right now. For life in the oceans, it’s probably the rate of change that matters.

To find a period analogous to the present, you have to go back at least 55 million years, to what’s known as the Paleocene-Eocene Thermal Maximum or PETM. During the PETM huge quantities of carbon were released into the

atmosphere, from where, no one is quite sure. Temperatures around the world soared by around ten degrees Fahrenheit, and marine chemistry changed dramatically. The ocean depths became so corrosive that in many places shells stopped piling up on the seafloor and simply dissolved. In sediment cores the period shows up as a layer of red clay sandwiched between two white layers of calcium carbonate. Many deepwater species of foraminifera went extinct.

Surprisingly, though, most organisms that live near the sea surface seem to have come through the PETM just fine. Perhaps marine life is more resilient than the results from places like Castello Aragonese and One Tree Island seem to indicate. Or perhaps the PETM, while extreme, was not as extreme as what's happening today.

The sediment record doesn't reveal how fast the PETM carbon release occurred. But modeling studies suggest it took place over thousands of years—slow enough for the chemical effects to spread through the entire ocean to its depths. Today's rate of emissions seems to be roughly ten times as fast, and there's not enough time for the water layers to mix. In the coming century acidification will be concentrated near the surface, where most marine calcifiers and all tropical corals reside. "What we're doing now is quite geologically special," says climate scientist Andy Ridgwell of the University of Bristol, who has modeled the PETM ocean.

Just how special is up to us. It's still possible to avert the most extreme acidification scenarios. But the only way to

do this, or at least the only way anyone has come up with so far, is to dramatically reduce CO_2 emissions. At the moment, corals and pteropods are lined up against a global economy built on cheap fossil fuels. It's not a fair fight.

Chapter 4: Bangladesh: The Coming Storm

BY DON BELT

Don Belt previously reported on the Indian subcontinent in September 2007 (Pakistan) and October 2008 (India). Jonas Bendiksen's last feature was on the melting Himalayan glaciers (April 2010).

WE MAY BE SEVEN MILLION SPECKS on the surface of Earth, but when you're in Bangladesh, it sometimes feels as if half the human race were crammed into a space the size of Louisiana. Dhaka, its capital, is so crowded that every park and footpath has been colonized by the homeless. To stroll here in the mists of early morning is to navigate an obstacle course of makeshift beds and sleeping children. Later the city's steamy roads and alleyways clog with the chaos of some 15 million people, most of them stuck in traffic. Amid this clatter and hubbub moves a small army of Bengali beggars, vegetable sellers, popcorn vendors, rickshaw drivers, and trinket salesmen, all surging through the city like particles in a flash flood. The countryside beyond is a vast watery flood-plain with intermittent stretches of land that are lush, green, flat as a parking lot—and wall-to-wall with human beings. In places you might expect to find solitude, there is none. There are no lonesome highways in Bangladesh.

We should not be surprised. Bangladesh is, after all, one of the most densely populated nations on Earth. It has more

people than geographically massive Russia. It is a place where one person, in a nation of 164 million, is mathematically incapable of being truly alone. That takes some getting used to.

So imagine Bangladesh in the year 2050, when its population will likely have zoomed to 220 million, and a good chunk of its current landmass could be permanently underwater. That scenario is based on two converging projections: population growth that, despite a sharp decline in fertility, will continue to produce millions more Bangladeshis in the coming decades, and a possible multifoot rise in sea level by 2100 as a result of climate change. Such a scenario could mean that 10 to 30 million people along the southern coast would be displaced, forcing Bangladeshis to crowd even closer together or else flee the country as climate refugees—a group predicted to swell to some 250 million worldwide by the middle of the century, many from poor, low-lying countries.

“Globally, we’re talking about the largest mass migration in human history,” says Maj. Gen. Muniruzzaman, a charismatic retired army officer who presides over the Bangladesh Institute of Peace and Security Studies in Dhaka.

“By 2050 millions of displaced people will overwhelm not just our limited land and resources but our government, our institutions, and our borders.” Muniruzzaman cites a recent war game run by the National Defense University in Washington, D.C., which forecast the geopolitical chaos that such a mass migration of Bangladeshis might cause in

South Asia. In that exercise millions of refugees fled to neighboring India, leading to disease, religious conflict, chronic shortages of food and fresh water, and heightened tensions between the nuclear-armed adversaries India and Pakistan.

Such a catastrophe, even imaginary, fits right in with Bangladesh's crisis-driven story line, which, since the country's independence in 1971, has included war, famine, disease, killer cyclones, massive floods, military coups, political assassinations, and pitiable rates of poverty and deprivation—a list of woes that inspired some to label it an international basket case. Yet if despair is in order, plenty of people in Bangladesh didn't read the script. In fact, many here are pitching another ending altogether, one in which the hardships of their past give rise to a powerful hope.

For all its troubles, Bangladesh is a place where adapting to a changing climate actually seems possible, and where every low-tech adaptation imaginable is now being tried. Supported by governments of the industrialized countries—whose greenhouse emissions are largely responsible for the climate change that is causing seas to rise—and implemented by a long list of international nongovernmental organizations (NGOs), these innovations are gaining credence, thanks to the one commodity that Bangladesh has in profusion: human resilience. Before this century is over, the world, rather than pitying Bangladesh, may wind up learning from her example.

Girl Power

National efforts have raised primary school enrollment to 16.7 million students, with an emphasis on girls, who now outnumber boys in school.

MORE THAN A THIRD OF THE WORLD'S PEOPLE live within 62 miles of a shoreline. Over the coming decades, as sea levels rise, climate change experts predict that many of the world's largest cities, including Miami and New York, will be increasingly vulnerable to coastal flooding. A recent study of 136 port cities found that those with the largest threatened populations will be in developing countries, especially those in Asia. Worldwide, the two cities that will have the greatest proportional increase in people exposed to climate extremes by 2070 are both in Bangladesh: Dhaka and Chittagong, with Khulna close behind. Though some parts of the delta region may keep pace with rising sea levels, thanks to river sediment that builds up coastal land, other areas will likely be submerged.

But Bangladeshis don't have to wait decades for a preview of a future transformed by rising seas. From their vantage point on the Bay of Bengal, they are already facing what it's like to live in an overpopulated and climate-changed world. They've watched sea levels rise, salinity infect their coastal aquifers, river flooding become more destructive, and cyclones batter their coast with increasing intensity—all changes associated with disruptions in the global climate.

On May 25, 2009, the people of Munshiganj, a village of

35,000 on the southwest coast, got a glimpse of what to expect from a multifoot rise in sea level. That morning a cyclone, called Aila, was lurking offshore, and its 70-mile-an-hour winds sent a storm surge racing silently toward shore, where the villagers, unsuspecting, were busy tending their rice fields and repairing their nets.

Urban Challenge

Sanitation systems are faltering as Bangladeshis crowd into cities.

Shortly after ten o'clock Nasir Uddin, a 40-year-old fisherman, noticed that the tidal river next to the village was rising "much faster than normal" toward high tide. He looked back just in time to see a wall of brown water start pouring over one of the six-foot earthen dikes that protect the village—its last line of defense against the sea.

Within seconds water was surging through his house, sucking away the mud walls and everything else. His three young daughters jumped onto the kitchen table, screaming as cold salt water swirled around their ankles, then up to their knees. "I was sure we were dead," he told me months later, standing in shin-deep mud next to a pond full of stagnant green water the color of antifreeze. "But Allah had other plans."

As if by a miracle, an empty fishing boat swept past, and Uddin grabbed it and hoisted his daughters inside. A few minutes later the boat capsized, but the family managed to

hang on as it was tossed by waves. The water finally subsided, leaving hundreds of people dead along the southwest coast and thousands homeless. Uddin and most of his neighbors in Munshiganj decided to hunker down and rebuild, but thousands of others set out to start a new life in inland cities such as Khulna and Dhaka.

THOUSANDS OF PEOPLE ARRIVE in Dhaka each day, fleeing river flooding in the north and cyclones in the south. Many of them end up living in the densely populated slum of Korail. And with hundreds of thousands of such migrants already, Dhaka is in no shape to take in new residents. It's already struggling to provide the most basic services and infrastructure.

Yet precisely because Bangladesh has so many problems, it's long served as a kind of laboratory for innovative solutions in the developing world. It has bounced back from crisis after crisis, proving itself far more resourceful than skeptics might have guessed. Dhaka is home to BRAC, the largest nonprofit in the developing world, held up as a model for how to provide basic health care and other services with an army of field-workers. Bangladesh also produced the global micro-finance movement started by Nobel Peace laureate Muhammad Yunus and his Grameen Bank.

And believe it or not, it's a population success story as well. To whittle its high birthrate, Bangladesh developed a grassroots family-planning program in the 1970s that has

lowered its fertility rate from 6.6 children per woman in 1977 to about 2.4 today—a historic record for a country with so much poverty and illiteracy. Fertility decline has generally been associated with economic improvement, which prompts parents to limit family size so they can provide education and other opportunities to their children. But Bangladesh has been able to reduce fertility despite its lack of economic development.

"It was very hard in the beginning," says Begum Rokeya, 42, a government health worker in the Satkhira District who's made thousands of home visits to persuade newlywed couples to use contraception and plan their family's size.

"This is a very conservative country, and men put pressure on women to have lots of children. But they began to see that if they immunized their kids, they wouldn't need to have a bunch of babies just so a few would survive. They like the idea of fewer mouths to feed."

Working in partnership with dozens of NGOs, Bangladesh has made huge strides in educating women and providing them with economic opportunities; female work-participation rates have doubled since 1995. Its economy is growing, helped by its garment-export industry. And Bangladesh has managed to meet an important UN Millennium Development Goal: Infant mortality dropped dramatically between 1990 and 2008, from 100 deaths per 1,000 births to 43—one of the highest improvement rates among low-income countries.

In Dhaka such successes are dwarfed by the

overwhelming poverty and the constant influx of villagers, prompting organizations, including BRAC, to get involved in helping village people figure out how to survive in a deteriorating environment. “Our goal is to prevent people from coming to Dhaka in the first place, by helping them adapt and find new ways of making a go of it in their villages,” says Babar Kabir, head of BRAC’s climate change and disaster management programs. “Big storms like Aila uproot them from the lives they know.”

IBRAHIM KHALILULLAH HAS LOST TRACK of how many times he’s moved. “Thirty? Forty?” he asks. “Does it matter?” Actually those figures might be a bit low, as he estimates he’s moved about once a year his whole life, and he’s now over 60. Somehow, between all that moving, he and his wife raised seven children who “never missed a meal,” he says proudly. He’s a warm, good-natured man, with gray hair cut short and a longish gray beard, and everything he says has a note of joy in it.

Khalilullah is a char dweller, one of the hundreds of thousands of people who inhabit the constantly changing islands, or chars, on the floodplains of Bangladesh’s three major rivers—the Padma, Jamuna, and Meghna. These islands, many covering less than a square mile, appear and vanish constantly, rising and falling with the tide, the season, the phase of the moon, the rainfall, and the flow of rivers upstream. Char dwellers will set out by boat to visit friends on another char, only to find that it’s completely

disappeared. Later they will hear through the grapevine that their friends moved to a new char that had popped up a few miles downstream, built their house in a day, and planted a garden by nightfall. Making a life on the chars—growing crops, building a home, raising a family—is like winning an Olympic medal in adaptation. Char dwellers may be the most resilient people on Earth.

There are tricks to living on a char, Khalilullah says. He builds his house in sections that can be dismantled, moved, and reassembled in a matter of a few hours. He always builds on a raised platform of earth at least six feet high. He uses sheets of corrugated metal for the outside walls and panels of thatch for the roof. He keeps the family suitcases stacked neatly next to the bed in case they're needed on short notice. And he has documents, passed down from his father, that establish his right to settle on new islands when they emerge—part of an intricate system of laws and customs that would prevent a million migrants from the south, say, from ever squatting on the chars. His real secret, he says, is not to think too much. "We're all under pressure, but there's really no point to worry. This is our only option, to move from place to place to place. We farm this land for as long as we can, and then the river washes it away. No matter how much we worry, the ending is always the same."

Even in the best of times, it's a precarious way of life. And these are not the best of times. In Bangladesh climate change threatens not just the coast but also inland communities like Khalilullah's. It could disrupt natural cycles

of precipitation, including monsoon rains and the Tibetan Plateau snowfall, both of which feed the major rivers that eventually braid their way through the delta.

But precisely because the country's geography is prone to floods and cyclones, Bangladeshis have gotten a head start on preparing for a climate-changed future. For decades they have been developing more salt-resistant strains of rice and building dikes to keep low-lying farms from being flooded with seawater. As a result, the country has actually doubled its production of rice since the early 1970s. Similarly its frequent cyclones have prompted it to build cyclone shelters and develop early-warning systems for natural disasters. More recently various NGOs have set up floating schools, hospitals, and libraries that keep right on functioning through monsoon season.

"Let me tell you about Bangladeshis," says Zakir Kibria, 37, a political scientist who serves as a policy analyst at Uttaran, an NGO devoted to environmental justice and poverty eradication. "We may be poor and appear disorganized, but we are not victims. And when things get tough, people here do what they've always done—they find a way to adapt and survive. We're masters of 'climate resilience.'"

Muhammad Hayat Ali is a 40-year-old farmer, straight as bamboo, who lives east of Satkhira, about 30 miles upstream of the coast but still within range of tidal surges and the salinity of a slowly rising sea. "In previous times this land was juicy, all rice fields," Ali says, his arm sweeping the landscape. "But now the weather has changed—

summer is longer and hotter than it used to be, and the rains aren't coming when they should. The rivers are saltier than before, and any water we get from the ground is too salty to grow rice. So now I'm raising shrimps in these ponds and growing my vegetables on the embankments around them." A decade ago such a pond would have been a novelty; now everyone, it seems, is raising shrimps or crabs and selling them to wholesalers for shipment to Dhaka or abroad.

Sometimes, though, adaptations backfire. Throughout southern Bangladesh, villages and fields are shielded from rivers by a network of dikes built by the government with help from Dutch engineers in the 1960s. During floods the rivers sometimes overflow the dikes and fill the fields like soup bowls. When the flood recedes, the water is trapped. The fields become waterlogged, unusable for years at a time.

Decades ago things got so bad in Satkhira—so many fields were water-logged, so many farmers out of work—that members of the local community used picks and shovels to illegally cut a 20-yard gap in an embankment, draining a huge field that had been waterlogged for nearly three years. In doing so, they were emulating Bengali farmers of earlier times, who periodically broke their embankments and allowed river water to enter their fields, rising and falling with the tides, until the deposited sediment raised the level of the land. But this time the villagers were charged with breaking the law.

Then a funny thing happened. The field, which had been

left open, acquired tons of sediment from the river and grew higher by five or six feet. The river channel deepened, and fishermen began to catch fish again. Finally a government study group came to survey the situation and wound up recommending that other fields be managed the same way. The villagers were vindicated, even hailed as heroes. And today the field is covered with many acres of rice.

"Rivers are a lifeline for this region, and our ancestors knew that," Kibria says as he walks an embankment. "Opening the fields connects everything. It raises the land level to make up for the rise in sea level. It preserves livelihoods and diversifies the kinds of crops that we can grow. It also keeps thousands of farmers and fishermen from giving up and moving to Dhaka."

BUT EVERY ADAPTATION, no matter how clever, is only temporary. Even at its sharply reduced rate of growth, Bangladesh's population will continue to expand—to perhaps more than 250 million by the turn of the next century—and some of its land will continue to dissolve. Where will all those people live, and what will they do for a living?

Many millions of Bangladeshis are already working abroad, whether in Western countries, in places such as Saudi Arabia and the United Arab Emirates, or in India, where millions fled during Bangladesh's 1971 war of independence against Pakistan and never returned. Millions more have slipped across the frontier in the decades since, prompting social unrest and conflict. Today

India seems determined to close and fortify its border, girding against some future mass migration of the type hypothesized in Washington. It's building a 2,500-mile security fence along the border, and security guards have routinely shot people crossing illegally into India. Interviews with families of victims suggest that at least some of the dead were desperate teenagers seeking to help their families financially. They had been shot smuggling cattle from India, where the animals are protected by Hinduism, to Muslim Bangladesh, where they can fetch up to $40 a head.

But if ten million climate refugees were ever to storm across the border into India, Maj. Gen. Muniruzzaman says, "those trigger-happy Indian border guards would soon run out of bullets." He argues that developed countries—not just India—should be liberalizing immigration policies to head off such a chilling prospect. All around Bangladesh bright, ambitious, well-educated young people are plotting their exit strategies.

And that's not such a bad idea, says Mohammed Mabud, a professor of public health at Dhaka's North South University and president of the Organization for Population and Poverty Alleviation. Mabud believes that investing in educating Bangladeshis would not only help train professionals to work within the country but also make them desirable as immigrants to other countries—sort of a planned brain drain. Emigration could relieve some of the pressure that's sure to slam down in the decades ahead. It's also a way to bolster the country's economy;

remittances sent back by emigrants account for 11 percent of the country's GDP. "If people can go abroad for employment, trade, or education and stay there for several years, many of them will stay," he says. By the time climate change hits hardest, the population of Bangladesh could be reduced by 8 to 20 million people—if the government makes out-migration a more urgent priority.

For now, the government seems more interested in making climate adaptation a key part of its national development strategy. That translates, roughly, into using the country's environmental woes as leverage in persuading the industrialized world to offer increased levels of aid. It's a strategy that's helped sustain Bangladesh throughout its short, traumatic history. Since independence, it has received tens of billions of dollars in international aid commitments. And as part of the accord produced at the United Nations Climate Change Conference in Copenhagen in 2009, nations of the developed world committed to a goal of $100 billion a year by 2020 to address the needs of poor countries on the front lines of climate change. Many in Bangladesh believe its share should be proportionate to its position as one of the countries most threatened.

"Climate change has become a kind of business, with lots of money flying around, lots of consultants," says Abu Mostafa Kamal Uddin, former program manager for the government's Climate Change Cell. "During the global financial meltdown, trillions of dollars were mobilized to save the world's banks," he says. "What's wrong with

helping the poor people of Bangladesh adapt to a situation we had nothing to do with creating?"

TWO YEARS AFTER the cyclone, Munshiganj is still drying out. Nasir Uddin and his neighbors are struggling to wring the salt water out of their psyches, rebuild their lives, and avoid being eaten by the tigers that prowl the village at night, driven from the adjacent Sundarbans mangrove forest in search of easy prey. Attacks have risen as population and environmental pressures have increased. Dozens of residents around Munshiganj have perished or been wounded in recent years—two died the week I was there—and some of the attacks occurred in broad daylight.

"It's bad here, but where else can we go?" Uddin says, surveying the four-foot-high mud platform where he's planning to rebuild his house with an interest-free loan from an NGO. This time he's using wood, which floats, instead of mud. The rice fields around his house are full of water, much of it brackish, and most local farmers have begun raising shrimps or crabs in the brine. Deep wells in the village have gone salty too, he says, forcing people to collect rainwater and apply to NGOs for a water ration, which is delivered by truck to a tank in the village and carried home in aluminum jugs, usually balanced on the heads of young women. "You should take a picture of this place and show it to people driving big cars in your country," says Uddin's neighbor Samir Ranjan Gayen, a short, bearded man who runs a local NGO. "Tell them it's a

preview of what South Florida will look like in 40 years."

As the people of Munshiganj can attest, there's no arguing with the sea, which is coming for this land sooner or later. And yet it's hard to imagine millions of Bangladeshis packing up and fleeing en masse to India, no matter how bad things become. They'll likely adapt until the bitter end, and then, when things become impossible, adapt a little more. It's a matter of national mentality—a fierce instinct for survival combined with a willingness to put up with conditions the rest of us might not.

Abdullah Abu Sayeed, a literacy advocate, explains it this way: "One day I was driving on one of the busiest streets in Dhaka—thousands of vehicles, all of them in a hurry—and I almost ran over a little boy, no more than five or six years old, who was fast asleep on the road divider in the middle of traffic. Cars were whizzing by, passing just inches from his head. But he was at peace, taking a nap in some of the craziest traffic in the world. That's Bangladesh. We are used to precarious circumstances, and our expectations are very, very low. It's why we can adapt to just about anything."

Chapter 5: Food Ark

BY CHARLES SIEBERT

Charles Siebert is the author of The Wauchula Woods Accord: Toward a New Understanding of Animals. Jim Richardson documented the importance of soil to our food supply in the September 2008 issue.

In China 90 percent of the wheat varieties cultivated just a century ago have disappeared. Experts estimate that we have lost more than half of the world's food varieties over the past century. As for the 8,000 known livestock breeds, 1,600 are endangered or already extinct.

All the food crops we eat today were developed and diversified about 10,000 years ago in these relatively few regions, first identified by the great Russian botanist Nikolay Vavilov in the early 20th century.

Why is this a problem? Because if disease or future climate change decimates one of the handful of plants and animals we've come to depend on to feed our growing planet, we might desperately need one of those varieties we've let go extinct. The precipitous loss of the world's wheat diversity is a particular cause for concern. One of wheat's oldest adversaries, *Puccinia graminis,* a fungus

known as stem rust, is spreading across the globe. The pestilence's current incarnation is a virulent and fast-mutating strain dubbed Ug99 because it was first identified in Uganda in 1999. It then spread to Kenya, Ethiopia, Sudan, and Yemen. By 2007 it had jumped the Persian Gulf into Iran. Scientists predict that Ug99 will soon make its way into the breadbaskets of India and Pakistan, then infiltrate Russia, China, and—with a mere hitch of a spore on an airplane passenger's shoe—our hemisphere as well.

Roughly 90 percent of the world's wheat is defenseless against Ug99. Were the fungus to come to the U.S., an estimated one billion dollars' worth of wheat would be at risk. Scientists project that in Asia and Africa alone the portion of wheat in imminent danger would leave one billion people without their primary food source. A significant humanitarian crisis is inevitable, according to Rick Ward of the Durable Rust Resistance in Wheat project at Cornell University.

The world's population is expected to reach seven billion people this year. By 2045 it could grow to nine billion. Some experts say we'll need to double our food production to keep up with demand as emerging economies consume more meat and dairy. Given the added challenges posed by climate change and constantly mutating diseases like Ug99, it is becoming ever more urgent to find ways to increase food yield without exacerbating the genetic anemia coursing through industrialized agriculture's ostensible abundance. The world has become increasingly dependent upon technology-driven, one-size-fits-all

solutions to its problems. Yet the best hope for securing food's future may depend on our ability to preserve the locally cultivated foods of the past.

IT TOOK MORE THAN 10,000 YEARS of domestication for humans to create the vast biodiversity in our food supply that we're now watching ebb away. Selectively breeding a wild plant or animal species for certain desirable traits began as a fitful process of trial and error motivated by that age-old imperative: hunger. Wild wheat, for example, drops its ripened kernels to the ground, or shatters, so that the plant can reseed itself. Early farmers selected out wheat that, due to a random genetic mutation, didn't shatter and was thus ideal for harvesting.

Farmers and breeders painstakingly developed livestock breeds and food crops well suited to the peculiarities of their local climate and environment. Each domesticated seed or breed was an answer to some very specific problem—such as drought or disease—in a very specific place. The North American Gulf Coast Native sheep, for example, thrives in high heat and humidity and has broad parasite resistance. On the remote Orkney Islands, North Ronaldsay sheep can live on nothing but seaweed. Zebu cattle are more resistant to ticks than other cattle. In Ethiopia a small, humpless, short-horned cattle breed called the Sheko is a good milk producer that withstands harsh conditions and has resistance to sleeping sickness.

Such adaptive traits are invaluable not only to local farmers but also to commercial breeders elsewhere in the world. Finnsheep, for example, long raised only by a small group of Finnish peasants, have become vital to the sheep industry because of their ability to produce large litters. The Fayoumi chicken, an indigenous Egyptian species dating back to the reign of the pharaohs, is in great demand as a prodigious egg layer with high heat tolerance and resistance to numerous diseases. Similarly, the rare Taihu pig of China is coveted by the world's pig breeders for its ability to thrive on cheap forage foods and its unusual fertility, regularly producing litters of 16 piglets as opposed to an average of 10 for Western breeds.

The irony is that the dangerous dwindling of diversity in our food supply is the unanticipated result of an agricultural triumph. The story is well-known. A 30-year-old plant pathologist named Norman Borlaug traveled to Mexico in 1944 to help fight a stem rust epidemic that had caused widespread famine. Crossing different wheat varieties from all over the world, he arrived at a rust-resistant, high-yield hybrid that helped India and Pakistan nearly double their wheat production—and saved a billion people from starvation. This so-called green revolution helped introduce modern industrialized agriculture to the developing world.

But the green revolution was a mixed blessing. Over time farmers came to rely heavily on broadly adapted, high-yield crops to the exclusion of varieties adapted to local conditions. Monocropping vast fields with the same genetically uniform seeds helps boost yield and meet

immediate hunger needs. Yet high-yield varieties are also genetically weaker crops that require expensive chemical fertilizers and toxic pesticides.

The same holds true for high-yield livestock breeds, which often require expensive feed and medicinal care to survive in foreign climates. The drive to increase production is pushing out local varieties, diluting livestock's genetic diversity in the process. As a result, the world's food supply has become largely dependent on a shrinking list of breeds designed for maximum yield: the Rhode Island Red chicken, the Large White pig, the Holstein cow. In short, in our focus on increasing the amount of food we produce today, we have accidentally put ourselves at risk for food shortages in the future.

One cautionary tale about the perils of relying on a homogenous food source revolves around the humble potato. High in the Peruvian Andes, where the potato was first domesticated, farmers still grow thousands of otherworldly looking varieties. Spanish ships in the late 16th century first brought the tuber to Europe, where by the early 1800s it had become a reliable backup to cereal crops, particularly in the cold, rain-soaked soils of Ireland. The Irish were soon almost wholly dependent on the potato as their food staple. And they were planting primarily one prodigious variety, the Lumper potato, whose genetic frailty would be cruelly exposed by *Phytophthora infestans,* as fearsome a foe of potatoes as stem rust is of wheat. In 1845 spores of the deadly fungus began spreading across the country, destroying nearly all the Lumpers in its path.

The resulting famine killed or displaced millions.

Current efforts to increase food production in the developing world—especially in Africa, largely bypassed by the green revolution—may only accelerate the pace at which livestock breeds and crop species disappear in the years to come. In pockets of Africa where high-yield seeds and breeds have been introduced, the results have been mixed at best. Countries like Zimbabwe, Zambia, and Malawi ended up sacrificing much of their crop diversity to the monocropping of imported, high-yield varieties subsidized by government programs and provided by aid organizations. Small farmers and pastoralists have gone deep into debt to pay for the "inputs"—the fertilizers, pesticides, high-protein feeds, and medication—required to grow these new plants and livestock in different climate conditions. They are like addicts, hooked on a habit they can ill afford in either economic and ecological terms.

ONE RESPONSE to the rapidly dwindling biodiversity in our fields has been to gather and safely store the seeds of as many different crop varieties as we can before they disappear forever. It's an idea first conceived by Russian botanist Nikolay Vavilov, who in 1926 had perhaps the least heralded scientific epiphany of the modern era. The son of a Moscow merchant who'd grown up in a poor rural village plagued by recurring crop failures and food rationing, Vavilov was obsessed from an early age with ending famine in both his native Russia and the world. In

the 1920s and ’30s he devoted himself to gathering seeds on five continents from the wild relatives and unknown varieties of the crops we eat, in order to preserve genes that confer such essential characteristics as disease and pest resistance and the ability to withstand extreme climate conditions. He also headed an institute (now called the Research Institute of Plant Industry, in St. Petersburg) tasked with preserving his burgeoning collection—what amounted to the first global seed bank.

It was on one expedition to Abyssinia (now Ethiopia) in 1926 that Vavilov had a vision in which he attained a vantage point high enough above the planet to see the handful of locations across the Earth where the wild relatives of our food crops had first been domesticated. Afterward he mapped out seven “centers of origin of cultivated plants,” which he described as the ancient birthing grounds of agriculture. “It is possible to witness there,” Vavilov wrote, “the great role played by man in the selection of the cultivated forms best suited to each area.”

Vavilov’s life story did not end happily. In 1943 one of the world’s foremost authorities on the potential cures for famine died of starvation in a prison camp on the Volga River, a victim of Stalin, who had deemed Vavilov’s seed-gathering efforts bourgeois science. By this time, Hitler’s army had already closed in on St. Petersburg (then Leningrad)—a desperate city that had lost more than 700,000 people to hunger and disease. The Soviets had ordered the evacuation of art from the Hermitage, convinced that Hitler had his sights set on the museum.

They had done nothing, however, to safeguard the 400,000 seeds, roots, and fruits stored in the world's largest seed bank. So a group of scientists at the Vavilov Institute boxed up a cross section of seeds, moved them to the basement, and took shifts protecting them. Historical documents later revealed that Hitler had, in fact, established a commando unit to seize the seed bank, perhaps hoping to one day control the world's food supply.

Although suffering from hunger, the seeds' caretakers refused to eat what they saw as their country's future. Indeed, by the end of the siege in the spring of 1944, nine of the institute's self-appointed seed guardians had died of starvation.

Vavilov's ideas have been modified in the years since. Today's scientists consider the regions he mapped to be centers of diversity rather than of origin, because it isn't clear whether the earliest domestication occurred there first. Yet Vavilov's vision of these regions as the repositories of the genetic diversity upon which the future of our food depends is proving more prescient than ever.

Today there are some 1,400 seed banks around the world. The most ambitious is the new Svalbard Global Seed Vault, set inside the permafrost of a sandstone mountain on the Norwegian island of Spitsbergen just 700 miles from the North Pole. Started by Cary Fowler in conjunction with the Consultative Group on International Agricultural Research, the so-called doomsday vault is a backup for all the world's other seed banks. Copies of their collections are stored in a permanently chilled, earthquake-

free zone 400 feet above sea level, ensuring that the seeds will remain high and dry even if the polar ice caps melt.

Fowler's Global Crop Diversity Trust recently announced what amounts to a recapitulation of Vavilov's worldwide seed-gathering expeditions: a ten-year initiative to scour the Earth for the last remaining wild relatives of wheat, rice, barley, lentils, and chickpeas in order to "arm agriculture against climate change." The hope is that this mad-dash scramble will allow scientists to pass along the vital traits of these rugged relatives, such as drought and flood tolerance, to our vulnerable crop varieties.

Still, storing seeds in banks to bail us out of future calamities is only a halfway measure. Equally worthy of saving is the hard-earned wisdom of the world's farmers, generations of whom crafted the seeds and breeds we now so covet. Perhaps the most precious and endangered resource is the knowledge stored in farmers' minds.

FORTY-YEAR-OLD Jemal Mohammed owns a five-acre, hillside farm outside the tiny hamlet of Fontanina in the Welo region of Ethiopia's northern highlands. It is in the heart of one of the centers of diversity that Nikolay Vavilov visited on his 1926 expedition.

Stepping foot on Mohammed's land is like tumbling back in time to an ancient way of farming. His circular, thatched-roof hut with walls of dried mud and straw is the same dwelling that has dotted Ethiopia's countryside for centuries. A pair of oxen lies to the right of the hut in the

shade of a jacaranda tree. Three or four chickens strut across a bare front yard. His fields, tilled with an ox-drawn plough and planted by hand, are a jumble of crops: tomatoes, onions, garlic, cilantro, gourds, sorghum, wheat, barley, chickpeas, and teff, a grain used to make injera, a flatbread.

The image of the traditional, small farmer's life is one of simplicity. And yet compared with the mechanized operations of modern agriculture, Mohammed's work is a dynamic and highly nuanced juggling act in the face of constant threats like drought, untimely downpours, and disease. He plants legumes and grain together to make the most of limited space. Such intercropping is also a natural way of fertilizing: The legumes growing at the base of the taller sorghum add nitrogen to the soil.

Welo was one of the regions hit hardest by the devastating 1984 famine in Ethiopia that killed hundreds of thousands. The experience is still seared in Mohammed's memory. He shows me a collection of hollowed-out gourds filled to the brim with what look to be colored pebbles. "I keep these stocks as my security, my backup," he says, looking down at the gourd casks filled with what I now realize are seeds. He has seeds for all of the crops growing in his fields. Mohammed's wife has rubbed the seeds in ash to protect them from weevils. "If we have total crop failure from drought or floods," he says, "I can at least plant my fields again."

I look into the intent faces of Mohammed and his family, then down at those ashen pebbles: all incipience, gnarled

knots of built-in urge, suggesting neither the centuries of selection that informed them nor the full-fleshed foods they'll eventually become, his own personal seed bank.

This is the beguiling paradox of seeds. They are, for all their obvious significance, so readily dismissible, especially by those of us in the well-fed world, who have forgotten where our food even comes from. Mohammed takes me to a farm across the road, where he and his neighbor lift a stone slab to reveal an earthen chamber six feet deep and wide: an emergency underground food store. In a few weeks, when the harvest is complete, they will line the chamber with straw, fill it with grain, and then pull the slab back over, allowing the earth's chill to keep it fresh.

When I ask how much they had to rely on their emergency store during the famine of 1984, they bow their heads and mumble a response before falling completely silent, their eyes welling with tears. My interpreter signals with a wave of a finger not to pursue the subject any further.

It is hard for them to even think of that time, he explains. They had sold their stored grain, never anticipating a sudden drought. Things got so bad that they had to eat all their reserves. A number of family members died of starvation. They were left with nothing but their seeds. Conditions were so inhospitable to planting that their empty stomachs soon had them planning to do the unthinkable: eat their seeds, their future.

ETHIOPIA'S EAST CENTRAL HIGHLANDS were once one of most

botanically diverse spots on Earth, but by the 1970s farmers here were down to growing just teff and a few varieties of wheat distributed to them for its high-yield potential. Today the region has been transformed: Local varieties of legumes and wheat are thriving again. Given the common depiction of Ethiopia as famine prone, it is startling to drive an hour northeast of Addis Ababa and see ample fields of a bushy, purple-seeded durum wheat, a variety found only in Ethiopia that is thriving across the country. Used for pasta, durum is largely resistant to stem rust. In one field is another local variety native to Ethiopia known as setakuri, which translates as “pride of women,” because it makes the sweetest bread. It is doing even better against stem rust.

Ethiopia’s turnaround can be traced in part to the efforts of renowned plant geneticist Melaku Worede, who received his Ph.D. from the University of Nebraska in 1972, then returned to Ethiopia with the goal of preserving—and rebuilding—the country’s rich biodiversity. Training a new generation of plant breeders and geneticists, Worede and his staff at the Plant Genetic Resources Centre in Addis Ababa set about collecting and storing native plants and seeds, known as landraces, from across the country. In 1989 Worede initiated the Seeds of Survival program, a network of community seed banks that save and redistribute the seeds of local farmers.

Worede is hopeful that new efforts to increase food production—such as the Gates Foundation’s Alliance for a Green Revolution in Africa—will not repeat the mistakes of

the past. Attempts are being made to include local farmers in decision-making. “The people planning this are aware that the first green revolution failed over time. There are some intelligent ideas,” Worede says. “But they are still placing too much emphasis on a narrow range of varieties. What about the rest? We’ll lose them. Believe me, I’m not against science. Why would I be? I’m a scientist. But contextualize it. Combine science with the local knowledge, the farmer’s science.”

Worede believes it is crucial to preserve the region’s diversity not just in seed banks but on the ground and in close consultation with local farmers. Although yield is obviously important to farmers, even more crucial is hedging their bets against famine, spreading the risk by growing many crops, over many seasons, in many locations. In this way if one crop gets diseased, or one harvest succumbs to drought, or one hillside is flooded, they have alternatives to fall back on.

The challenge has been to show it’s possible to increase productivity without sacrificing diversity. Worede wanted to prove that deciding between having enough to eat today and preserving food biodiversity for tomorrow is a false choice. And he has done precisely that. He has taken the varieties farmers selected for their adaptability and determined which of them promise the best yield. The use of high-yielding local seeds—in combination with natural fertilizers and techniques such as intercropping—has improved yield as much as 15 percent above that of the imported, high-input varieties. A parallel effort is under

way with local indigenous livestock breeds. Keith Hammond, a UN expert on animal genetics, says that in 80 percent of the world's rural areas the locally adapted genetic resources are superior to imported breeds.

Still, a 15 percent increase is far from the doubling of our food supply experts say we'll need in future decades. Preserving food diversity is only one of many strategies we'll need to meet that challenge, but it is a crucial one. As the world warms, and the environment becomes less hospitable to the breeds and seeds we now rely on for food, humanity will likely need the genes that allow plants and animals to flourish in, say, the African heat or in the face of recurring blight. Indeed, Worede thinks scientists may well find the Ug99-resistant varieties they're looking for in Ethiopia's fields. "Even if the disease mutates into a new form, it will not wipe out everything here. That is the advantage of diversity."

Yet Worede balks at the idea of the developed world treating Vavilov centers like Ethiopia as wild seed banks from which to withdraw traits whenever the next plague strikes. He cites the outbreak in the early 1970s of yellow dwarf virus, which threatened to wipe out the world's barley crop. A U.S. scientist who had come to Ethiopia in the 1960s had happened to grab some barley samples from a field for his own study. When the virus hit, he handed over the samples to one of the scientists trying to stop the virus. Sure enough they found a resistant gene. "It changed everything," says Worede, "at no cost to them. No genetic engineering, nothing. Just a natural source of resistance

taken from the very part of Ethiopia where people were suffering from starvation."

Mohammed and his neighbor stood in silence above their own private earthen seed bank that afternoon in Welo. Since the famine of 1984, they don't even think of selling any grain until they know what the harvest has brought. I asked whether the bounty I'd seen in their fields had them feeling a bit more secure and optimistic.

"It will be nice to have some extra money," Mohammed began, "so we can send our kids to school in good clothes, but…" He paused, looking over at his neighbor, then gave an answer I've come to think might perfectly describe the attitude we all should adopt when it comes to securing our future food supply.

"We're positive," Mohammed said. "But we're very sensitive to risk."

Chapter 6: Girl Power: Machisma

BY CYNTHIA GORNEY

Cynthia Gorney reported on child brides for our June issue. John Stanmeyer documented sacred rituals for our single-topic issue on water, which won a 2011 National Magazine Award.

JOSÉ ALBERTO, MURILO, GERALDO, ANGELA, PAULO, EDWIGES, VICENTE, RITA, LUCIA, MARCELINO, TERESINHA. That makes 11, right? Not including the stillbirth, the three miscarriages, and the baby who lived not quite one full day. Dona Maria Ribeiro de Carvalho, a gravelly-voiced Brazilian lady in her 88th year, completed the accounting of her 16 pregnancies and regarded José Alberto, her oldest son, who had come for a Sunday visit and was smoking a cigarette on her couch. "With the number of children I had," Dona Maria said mildly, her voice conveying only the faintest reproach, "I should have more than a hundred grandchildren right now."

José Alberto, who had been fishing all morning at the pond on his ranch, was still in his sweatpants. His mother's front room in the mid-Brazil town of São Vicente de Minas was just big enough to contain three crowded-in armchairs, a television, numerous family photos, framed drawings of Jesus and the Blessed Virgin, and the black vinyl couch upon which he, Professor Carvalho, retiring head of his university's School of Economics and one of the most eminent Brazilian demographers of the past half century,

now reclined. He put his feet up and smiled. He knew the total number of grandchildren, of course: 26. For much of his working life, he had been charting and probing and writing about the remarkable Brazilian demographic phenomenon that was replicated in miniature amid his own family, who within two generations had crashed their fertility rate to 2.36 children per family, heading right down toward the national average of 1.9.

That new Brazilian fertility rate is below the level at which a population replaces itself. It is lower than the two-children-per-woman fertility rate in the United States. In the largest nation in Latin America—a 191-million-person country where the Roman Catholic Church dominates, abortion is illegal (except in rare cases), and no official government policy has ever promoted birth control—family size has dropped so sharply and so insistently over the past five decades that the fertility rate graph looks like a playground slide.

And it's not simply wealthy and professional women who have stopped bearing multiple children in Brazil. There's a common perception that the countryside and favelas, as Brazilians call urban slums, are still crowded with women having one baby after another—but it isn't true. At the demographic center Carvalho helped found, located four hours away in the city of Belo Horizonte, researchers have tracked the decline across every class and region of Brazil. Over some weeks of talking to Brazilian women recently, I met schoolteachers, trash sorters, architects, newspaper reporters, shop clerks, cleaning ladies, professional

athletes, high school girls, and women who had spent their adolescence homeless; almost every one of them said a modern Brazilian family should include two children, ideally a *casal,* or couple, one boy and one girl. Three was barely plausible. One might well be enough. In a working-class neighborhood on the outskirts of Belo Horizonte, an unmarried 18-year-old affectionately watched her toddler son one evening as he roared his toy truck toward us; she loved him very much, the young woman said, but she was finished with childbearing. The expression she used was one I'd heard from Brazilian women before: *"A fábrica está fechada."* The factory is closed.

The emphatic fertility drop is not just a Brazilian phenomenon. Notwithstanding concerns over the planet's growing population, close to half the world's population lives in countries where the fertility rates have actually fallen to below replacement rate, the level at which a couple have only enough children to replace themselves—just over two children per family. They've dropped rapidly in most of the rest of the world as well, with the notable exception of sub-Saharan Africa.

For demographers working to understand the causes and implications of this startling trend, what's happened in Brazil since the 1960s provides one of the most compelling case studies on the planet. Brazil spans a vast landmass, with enormous regional differences in geography, race, and culture, yet its population data are by tradition particularly thorough and reliable. Pieces of the Brazilian experience have been mirrored in scores of other countries, including

those in which most of the population is Roman Catholic—but no other nation in the world seems to have managed it quite like this.

"What took 120 years in England took 40 years here," Carvalho told me one day. "Something *happened."* At that moment he was talking about what happened in São Vicente de Minas, the town of his childhood, where nobody under 45 has a soccer-team-size roster of siblings anymore. But he might as well have been describing the entire female population of Brazil. For although there are many reasons Brazil's fertility rate has dropped so far and so fast, central to them all are tough, resilient women who set out a few decades back, without encouragement from the government and over the pronouncements of their bishops, to start shutting down the factories any way they could.

Encountering women under 35 who've already had sterilization surgery is an everyday occurrence in Brazil, and they seem to have no compunctions about discussing it. "I was 18 when the first baby was born—wanted to stop there, but the second came by accident, and I am *done,"* a 28-year-old crafts shop worker told me in the northeastern city of Recife, as she was showing me how to dance the regional two-step called the *forró.* She was 26 when she had her tubal ligation, and when I asked why she'd chosen irreversible contraception at such a young age—she's married, what if she and her husband change their minds?—she reminded me of son number two, the accident. Birth

control pills made her fat and sick, she said. And in case I'd missed this part: She was done.

So why two? Why not four? Why not the eight your grandmother had? Always the same answer—"Impossible! Too expensive! Too much work!" With the facial expression, the widened eyes and the startled grin that I came to know well: It's the 21st century, *senhora,* are you nuts?

Population scholars like José Alberto Carvalho maintain a lively argument about the multiple components of Brazil's fertility plunge. ("Don't let anybody tell you they know for sure what caused the decline," a demographer advised me at Cedeplar, the university-based study center in Belo Horizonte. "We'll never have a winner as the best explanation.") But if one were to try composing a formula for crashing a developing nation's fertility rate without official intervention from the government—no China-style one-child policy, no India-style effort to force sterilization upon the populace—here's a six-point plan, tweaked for the peculiarities of modern Brazil:

1. Industrialize dramatically, urgently, and late, causing your nation to hurtle through in 25 years what economists used to think of as a century's worth of internal rural-to-urban relocation of its citizens. Brazil's military rulers, who seized power in a 1964 military coup and held on through two decades of sometimes brutal authoritarian rule, forced the country into a new kind of economy, one that has concentrated work in the cities, where the housing is cramped, the favela streets are dangerous, babies look

more like new expense burdens than like future useful farmhands, and the jobs women must take for their families' survival require leaving home for ten hours at a stretch.

2. Keep your medications mostly unregulated and your pharmacy system over-the-counter, so that when birth control pills hit the world in the early 1960s, women of all classes can get their hands on them, even without a doctor's prescription, if they can just come up with the money. Nurture in these women a particularly dismissive attitude toward the Catholic Church's position on artificial contraception. (See number 4.)

3. Improve your infant and child mortality statistics until families no longer feel compelled to have extra, just-in-case babies on the supposition that a few will die young. Compound that reassurance with a national pension program, relieving working-class parents of the conviction that a big family will be their only support when they grow old.

4. Distort your public health system's financial incentives for a generation or two, so that doctors learn they can count on higher pay and more predictable work schedules when they perform cesareans rather than waiting for natural deliveries. Then spread the word, woman to woman, that a public health doctor who has already begun the surgery for a cesarean can probably be persuaded to throw in a discreet tubal ligation, thus ensuring a thriving, decades-long publicly supported gray market for this permanent method of contraception. Brazil's health system didn't formally recognize voluntary female sterilization until 1997.

But the first time I ever heard the phrase “a fábrica está fechada,” it was from a 69-year-old retired schoolteacher who had her tubes tied in 1972, after her third child was born. This woman had three sisters. Every one of them underwent a ligation. Yes, they were all Catholic. Yes, the church hierarchy disapproved. No, none of them much cared; they were women of faith, but in some matters the male clergy is perhaps not wholly equipped to discern the true will of God. The lady was pouring tea into china cups at her dining table as we talked, and her voice was matter-of-fact. “Everyone was doing it,” she said.

5. Introduce electricity and television at the same time in much of the nation’s interior, a double disruption of traditional family living patterns, and then flood the airwaves with a singular, vivid, aspirational image of the modern Brazilian family: affluent, light skinned, and small. Scholars have tracked the apparent family-size-shrinking influence of *novelas,* Brazil’s Portuguese-language iterations of the beloved evening soap operas, or *telenovelas,* that broadcast all over Latin America, each playing for months, like an endless series of bodice-ripper paperbacks. One study observes that the spread of televisions outpaced access to education, which has greatly improved in Brazil, but at a slower pace. By the 1980s and ’90s all of Brazil was dominated by the Globo network, whose prime-time novelas were often a central topic of conversation; even now, in the era of multichannel satellite broadcasting, you can see café TVs turned to the biggest Globo novela of the season.

While I was there it was *Passione,* featuring the racked-by-secrets industrialist Gouveia family, who were all very good-looking and loaded up with desirable possessions: motorcycles, chandeliers, racing bicycles, airplane tickets, French high-heeled shoes. The widow Gouveia, resolute and admirable, had three kids. Well, four, but one was a secret because he was born out of wedlock and had been shipped off to Italy in infancy because…uh, never mind. The point is that there were not many Gouveias, nor were there big families anywhere else in the unfathomably complicated plotline.

"We asked them once: 'Is the Globo network trying to introduce family planning on purpose?'" says Elza Berquó, a veteran Brazilian demographer who helped study the novelas' effects. "You know what they answered? 'No. It's because it's much easier to write the novelas about small families.'"

And, finally, number 6: Make all your women Brazilians.

This is volatile territory, Brazil and women. Machismo means the same thing in the Portuguese of Brazil as it does in the rest of the continent's Spanish, and it has been linked to the country's high levels of domestic violence and other physical assaults on women. But the nation was profoundly altered by the *movimento das mulheres,* the women's movement of the 1970s and '80s, and no American today is in a position to call Brazil retrograde on matters of gender equity. When President Dilma Rousseff was running for office last year, the fiercest national

debates were about her political ideas and affiliations, not whether the nation was ready for its first female president. One of Rousseff's strongest competitors, in fact—a likely contender in future elections—was a female senator.

Brazil has high-ranking female military officers, special police stations run by and for women, and the world's most famous female soccer player (the one-name-only dazzling ball handler Marta). When I spent an evening in the city of Campinas with Aníbal Faúndes, a Chilean obstetrics professor who immigrated decades ago to Brazil and has helped lead national studies of reproductive health, Faúndes returned again and again to what he regards as the primary force pushing fertility change in his adopted country. "The fertility rate dropped because women decided they didn't want more children," he said. "Brazilian women are tremendously strong. It was just a matter of them deciding, and then having the means to achieve it."

The Cytotec episode offers sober but illuminating evidence. Cytotec is the brand name for a medication called misoprostol, which was developed as an ulcer treatment but in the late 1980s became internationally known as an early-abortion pill—part of the two-drug combination that included the medication known as RU-486. Even before the rest of the world received the news about pill-induced abortion, though—it entered the French and Chinese marketplaces in 1988, amid great controversy, and was subsequently approved in the U.S. for pregnancy termination—Brazilian women had figured it out on their own. No publicity campaign explained misoprostol;

this was pre-Internet, remember, and Brazilian law prohibits abortion except in cases of rape or risk to the woman's life.

But that law is ignored at every level of society. "Women were telling each other what the dose was," says Brazilian demographer Sarah Costa, director of the New York City–based Women's Refugee Commission, who has written about Brazil's Cytotec phenomenon for the medical journal the *Lancet.* "There were street vendors selling it in train stations. Most public health posts at that time were not providing family planning services, and if you are motivated to regulate your fertility, even if you have poor services and poor information, you'll ask somebody, What can I do? And the information *will* flow."

The open availability of Cytotec didn't last long. By 1991 the Brazilian government had put restrictions on it; today it is available only in hospitals, although women assured me that packs of Cytotec could still be obtained over the Internet or in certain flea markets. But the public health service now pays for sterilizations and other methods of birth control. Illegal abortion flourishes, in circumstances ranging from medically reliable to scary. It may not be entirely easy or safe for a Brazilian woman to keep her family small, but there's no shortage of available ways to do so. And in every respect, women of all ages told me, this is what they now expect of themselves—and what contemporary Brazil, in turn, appears to expect from them.

"Look at the apartments," said a 31-year-old Rio de Janeiro marketing executive named Andiara Petterle. "They're designed for a maximum of four people. Two

bedrooms. In the supermarkets, even the labels on frozen foods—always for four people."

The company Petterle founded specializes in sales research on Brazilian women, whose buying habits and life priorities seem to have been upended just in the years since Petterle was born. It wasn't until 1977, she reminded me, that the nation legalized divorce. "We've changed so fast," she said. "We've found that for many young women, their first priority now is their education. The second is their profession. And the third is children and a stable relationship."

So raising children hasn't vanished from these modern priorities, Petterle said—it's just lower on the list, and a tougher thing to juggle now. She has no children herself, although she hopes to someday. As Petterle talked, I heard what was becoming a familiar refrain: Contemporary Brazilian life is too expensive to accommodate more than two kids. Much of the public school system is *ruim*—useless, a disaster—people will tell you, and families scrape for any private education they can afford. The nationwide health system is ruim too, many insist, and families scrape for any private medical care they can afford. Clothing, books, backpacks, cell phones—all these things are costly, and all must somehow be obtained. And everything a young family might need is now available, as the mall windows relentlessly remind passing customers, with *financiamento,* short-or long-term.

Want your child to have that huge stuffed beagle, that

dolly set in the fancy gift box, that four-foot-long, battery-powered, ride-on SUV? Buy it on the installment plan—with interest, of course. Consumer credit has exploded throughout Brazil, reaching middle-and working-class families that two decades ago had no access to these kinds of discretionary purchases paid off over time. While I was in Brazil, the business magazine *Exame* ran a cover story on the nation's new multi-class consumerism. The São Paulo journalist who wrote the story, Fabiane Stefano, described the bustle she witnessed inside a travel agency that had recently opened in a downscale city neighborhood. "Every five minutes a new person came in," she said. "Eighty percent of these people were going to the Northeast to see family. It takes three days to get there by bus, only three hours by plane." This was each customer's first time flying. "The guy had to explain to them that in an airplane they wouldn't see their luggage for a while."

It would be a gross oversimplification to suggest that Brazilians are having fewer children just because they want to spend more money on each one. But these questions about material acquisition—how much everything now costs, and how much everyone now desires—both interested and troubled nearly every Brazilian woman I met. Smaller family size has been credited with helping boost the economies of rapidly developing countries, especially the mammoth five now referred to as BRICS: Brazil, Russia, India, China, South Africa. National economic growth brings no assurances of family well-being, though, unless that prosperity is managed thoughtfully and invested

in coming generations. “This is something I’ve been thinking about, the way we’re dropping the fertility rate in Brazil and the other BRICS countries, but I don’t see any real work on getting more ethical,” says the marketer Andiara Petterle. “We could be just *one* billion people in the world, and with the mentality we have now, we could be consuming just as many resources.”

The morning I had coffee with a group of young São Paulo professional women, we sat at a sidewalk table across from a shop that carried eight different glossy parenting magazines. Each was thick with ads: the Bébé Confort Modulo Clip convertible stroller; the electronic “cry analyzer” to identify the reason your baby is crying; the wall-mounted DVD player that projects moving images over the crib (“Distracts better than a mobile!”). We studied the fashion photographs of beautiful toddlers in knits and aviator sunglasses and fake furs. “Look at these kids,” said Milene Chaves, a 33-year-old journalist, her voice hovering between admiration and despair. She turned the page. “And it seems you have to have a decorated room too. I don’t need a decorated room like this.”

Chaves had a long-term boyfriend but has no children, not yet. “And when I do, I want to simplify things,” she said. The half dozen friends around her agreed, the magazines still open on the table before us: attractive objects, they said, but so excessive, so disturbingly too much. These São Paulo women were in their 20s and 30s, with two children or one or none. They followed precisely the patterns described to me by national demographers. When

I asked them whether they ever felt nostalgia for the less materialistic life of their elders, two generations back—eight children here, ten there, with nobody expecting decorators to gussy up the sleeping quarters—I was able to make out, among the hooting, the word *presa.* Imprisoned.

But their answers were nearly drowned out by their laughter.

Chapter 7: Rift in Paradise: Africa's Albertine Rift Valley

BY ROBERT DRAPER

Robert Draper is a contributing writer for the magazine who reported on Afghanistan's opium crop in the February issue. He and photographer Pascal Maitre have collaborated on stories in Somalia and Madagascar. If we could please get the file back by COB Monday, we should be done! Fantastic work, I knowthis was a bit of a piecemeal project—not easy!

The Mwami remembers when he was a king of sorts. His judgment was sovereign, his power unassailable. Since 1954 he has been the chief of the Masisi territory, an undulating pastoral region in the eastern Democratic Republic of the Congo, the same as his father and his grandfather before him. Though his given name is Sylvestre Bashali, the other chiefs simply address him as doyen—senior-most. For all of his adult life, the Mwami would receive newcomers to Masisi. They brought him livestock or other gifts. He in turn parceled out land as he saw fit. Today the chief sits on a dirty couch in a squalid hovel in Goma, the Congolese city several hours south of Masisi. His domain is now the epicenter of a humanitarian crisis that has lasted for decades, yet largely eludes the world's attention. Masisi has been overtaken—by thousands of

Tutsi and Hutus refugees returning from Rwanda to what they claim is their lawful property; by tribal militias aiming to acquire land by force; by cattlemen from neighboring countries searching for less-cluttered pastures; by hordes of itinerants from all over this fertile and dangerously overpopulated region of east Africa seeking somewhere, anywhere, to eke out a living. Recently, a member of the Tutsi rebel army seized the Mwami's 200-acre estate, forcing him, humiliated and fearing for his safety, to retreat to this shack in Goma.

The city is a hornet's nest. As recently as two decades ago, Goma's population was perhaps 50,000. Now it is at least ten times that number. Armed males in uniform stalk its raggedy unlit streets with no one to answer to. Streaming out of the outlying forests and into the city market is a 24/7 procession of boys ferrying immense sacks of charcoal on bicycles or wooden scooter-like chikudus. North of the city limits seethes the Nyiragongo volcano, last heard from in 2002, when its lava roared through town and wiped out Goma's historic Belgian district. To the east lies the silver cauldron of Lake Kivu—so choked with carbon dioxide and methane from the city's organic discharge that some scientists predict an eruption will one day kill everyone in and around Goma.

The Mwami, like so many others far less privileged, has run out of options. His stare is one of regal aloofness. Yet despite his cufflinks and manicured gray beard, he is not a chief here in Goma. He is only Sylvestre Bashali, a man swept into the hornet's nest, with no land left for him to

parcel out. As his guest, a journalist from the West, I have brought no gifts, only demeaning questions. “Yes, of course my power has been greatly affected,” the Mwami snaps at me. “When others back up their claims with guns, there is nothing I can do.”

The reign of the Mwamis is finished in this corner of East Africa, which has become a staging ground for violence of mind-reeling proportions in the past few decades: The murder and child abductions of tens of thousands in northern Uganda, the massacre of close to a million in the genocides of Rwanda and Burundi, followed by multiple civil wars in the eastern Congo, the last of which is estimated to have killed more than 3 million people, largely through disease and starvation—the deadliest since World War II. Armed conficts that started in one country have seeped across borders and turned into proxy wars, with the region’s various governments often backing a numbing jumble of acronymned rebel militia groups—the LRA, RPF, FDLR, CNDP, RCD, ADFLC, MLC, the list goes on—each vying for power and resources in one of the richest landscapes in Africa.

The horrific violence that has occurred in this place—and continues in the lawless Congo despite a 2009 peace accord—is impossible to understand in simplistic terms. But there is no doubt geography has played a role. Erase the borders of Uganda, DRC, Rwanda, and Burundi and you see what unites these disparate political entitites: a landscape shaped by the violent forces of shifting plate tectonics. The East African Rift bisects the horn of Africa

into two—the Nubian plate to the west and the Somalian plate to the east—before forking on either side of Uganda. The western branch of the rift contains Africa's Great Lakes, where the deep rift has filled with water, and is close to the volcanic Virunga and Rwenzori mountain ranges.

Called the Albertine Rift Valley (after Lake Albert) this three thousand square mile geological crease of lowland forests, snow-capped mountains, fertile savannahs, and chain of lakes is Africa's most fecund and biodiverse region, the home of mountain gorillas, okapi, lions, hippos, and elephants, dozens of rare bird and fish species, not to mention a bounty of minerals ranging from gold and diamonds to the key microchip component known as coltan. In the 19th century European explorers like David Livingstone and John Speke came here searching for the source of the Nile River. They gazed in awe at the profusion of lush vegetation and vast bodies of water, according to the scholar Jean-Pierre Chretien: "In the heart of black Africa, the Great Lakes literally dazzled the whites."

The paradox of the Albertine Rift Valley is that its very richness has led to scarcity. People have crowded into this area because of its fertile volcanic soil, its plentiful rainfall, its biodiversity, and an altitude that protects it from malaria and tsetse fly. As the population soared, more and more forest was cut down to increase farm and grazing land. Even in the 19th century the paradise that visitors beheld was already wracked with a central preoccupation: Is there enough for everyone?

Today that question hangs over every square inch of the

Albertine Rift Valley, where the birth rates are among the highest in the world, and where violence, between humans and against animals, has erupted in a horror show of land-grabs, spastic waves of refugees, mass rapes, and plundered national parks—the last places on Earth where wildlife strives to survive undisturbed by humans. For the impoverished residents of the region, overcrowding has spawned an anxiety so primal and omnipresent that one hears the same plea over and over again.

We want land!

The suspected lion killer sits near the shore of Lake George and plays a vigorous board game, known as omweso, with one of his fellow cattlemen. He looks up, introduces himself as Eirfazi Wamana, and says he cannot tell me his age nor the number of his children. “We Africans don’t count our off-spring,” he declares, “because you mizungu don’t like us to produce so many children.” Mizungu is slang for whites in this part of the world. Wamana offers a wry smile and says, “You don’t have to beat around the bush. Some lions were killed here, and the rangers came in the middle of the night and arrested me.”

In late May of 2010, two rangers in Uganda’s Queen Elizabeth National Park saw vultures hovering over a field about a kilometer from Wamana’s village of Hamukungu and discovered the dead bodies of five poisoned lions. Nearby were two cow carcasses that had been sprayed with a bluish chemical. Early intelligence pointed to

Wamana, but he was released for lack of evidence. Another suspect fled the area. “They held me for a day,” Wamana says, “but they have not released me from their investigation. I am not running away.”

Hamukungu village sits at the northern edge of the park, where the predominant tourist attraction is its population of lions, which has dwindled by 40 percent in less than a decade. “The number of villagers has increased,” says Wilson Kagoro, the park’s community conservation warden, “as has the number of cattle. And this has created a big conflict between them and us. They sneak into the park late at night to let their cattle graze. When this happens, the lions feast on the cows.” Given that parkland grazing is illegal, the aggrieved pastoralists are left with no recourse. But that does not mean that they are without countermeasures.

“We are surviving on God’s mercy,” Wamana says when I ask how so many people manage to survive on so little land. “The creation of this national park has made us so poor! People have to live on the land!” It’s a common complaint among the overcrowded villages that ring the region’s networks of parks and reserves. Queen Elizabeth and many of its neighboring parks in Uganda were established in the 1950s and 60s with the recognition that this region had the highest density of large mammals of any place on Earth—31.4 tonnes per square kilometer in Queen Elizabeth National Park. But social and political upheaval has made it difficult to protect the wildlife. Over decades, poachers and desperate villagers have raided

the parks and decimated the populations of elephant, hippos, and lions. By 2006 large mammal biomass was down to 9.5 tonnes in Queen Elizabeth, according to Andrew Plumptre, director of the Albertine Rift Program of the Wildlife Conservation Society.

The legendary Virunga National Park in the eastern Congo—Africa's oldest as it was founded in 1925—is the most imperiled by the overpopulated region's frantic land-grabbing. The countryside, once teeming with charismatic megafauna, is eerily vacant. The park's lodges are gutted. Since the Rwandan genocide of 1994, all but the eastern sliver of the park, which hosts its famed mountain gorilla population, has been closed to tourists. The park is a war zone.

Rodrigue Mugaruka is the warden of Virunga's central sector of Rwindi. He is a former child soldier who participated in the 1997 overthrow of Mobutu Sese Seko, the long-time dictator of the DRC (then called Zaire). In eastern Congo the vacuum created by Mobutu's exit unleashed fierce competition among proxy armies and various militias for its diamonds, gold, copper, and coltan. Now Mugaruka is doing battle with those militias—called Mai-Mai fighers—who control illegal fishing and charcoal production in ten villages that have cropped up inside the park surrounding Lake Edward. He had recently regained control of the sector from thousands of Congolese soldiers stationed here to monitor the mines. "They're supposed to be protecting the park. Instead they were destroying it. The government wasn't paying them so they were killing the

wildlife for food."

Mugaruka's efforts to enforce park regulations do not sit well with the tens of thousands of Congolese who have fled areas of conflict and taken up residence in the villages. In the fishing hamlet of Vitchumbi, the warden orders park rangers to chop up, douse in kerosene, and set fire to several unlicensed fishing boats, illegal nets, and bags of charcoal while the villagers look on bitterly. In a fishing boat dented from gunfire, he ferries us to Lulimbi village, from which we drive to the Ishasha River bordering Uganda, where 80 per cent of the park's hippo population was slaughtered and sold for bush meat by militias before the park rangers recently took control of the area. Later we head to the park's northern Tshiaberimu sub-sector, where an armed patrol subsidized by the Gorilla Organization provides round-the-clock protection to a family of ten mountain gorillas from villagers who have been encouraged by politicians to kill the apes and claim the parkland.

Rodrigue Mugaruka knows that he is a marked man. The Mai-Mais—and the Congolese businessmen who fund them—have designated him as a target. "Their objective is to chase us out of the park for good," says the warden. "When we seize a boat and a net, the businessmen tell the Mai-Mais, 'Before we put another net in the water, you must go kill a ranger.' Three of mine have been killed in the lake. If you consider the whole area, more than 20 rangers have been killed."

Last February Mugaruka discovered a huge supply of rice that was illegally grown inside the park. He ordered the

rice burned. A few days later, several of his men were waylaid by about 50 Mai-Mai fighters at the park entrance. Eight were shot to death. Government officials soon received a petition signed by 150,000 residents demanding that Virunga National Park be reduced in size by nearly 90 per cent. The petitioners gave the government three months to release this land to them. After that, warned the petition, the residents would all grow crops in the park —and defend their activities with arms.

The document was, in effect, a declaration of war against Warden Mugaruka and his outnumbered rangers.

We want land!

The speaker is Charles, a 24-year-old sitting on a freshly cut log in a forest, a machete in his hand. He does not belong here, in Uganda's Kagombe Forest Reserve. Then again, maybe he does. No less than the Minister of the Interior visited Charles and the other Kagombe inhabitants recently. "He told us we can stay a while," says Charles with a grin. The minister's political cronies, it would seem, have an election coming up—and in this part of the world, the best way to placate voters is to promise them land.

Charles and a few other pioneering young villagers moved into the forest in 2006. "We'd been living on our grandparents' property, but there were too many people on the land already," he says. "We heard people talk about how there was free land this way." Apparently a migrant tribe, the Bachinga, had already begun to settle in

Kagombe, and when the National Forest Authority tried to evict them, Uganda's President Yoweri Musevini—himself facing reelection—issued an executive order forbidding such action. Thereupon a few local politicians urged the indigenous Byanyora tribe, which included Charles and his friends, to grab some forestland as well, lest all of Kagombe be inhabited by non-locals.

Charles and his friends each claimed about seven acres of timberland and began slashing away. They built grass-thatched huts, feed storage sheds, roads, and a church. They planted maize, bananas, cassava, and Irish potatoes. Then they sent for their wives and began to have more children. Today Charles is one of about 2,000 inhabitants in the forest reserve and has no desire to leave. "We're very well off here," he says.

The forest, meanwhile, is a smoky wasteland, razed for miles in all directions. The damage goes beyond the aesthetic: Kagombe serves as a wildlife corridor for elephants, lions, buffalos, and other animals migrating from adjacent refuges in northern Uganda, the DRC, Rwanda, and Tanzania. As Sarah Prinsloo of the Wildlife Conservation Society observes, "The health of the wildlife population in these national parks is dependent on corridors like Kagombe." The habitat destruction of the corridor has contributed to a plunging animal birth rate throughout the region. In Kagombe itself, most wildlife has vanished.

The forestry agency's sector manager of the area, Patrick Kaketo, contemplates the environmental

devastation with a despairing smile. “They’re cutting all of this down,” Kaketo says. “And we can’t touch them. For us, it’s a kind of psycho-professional torture.”

How did Africa’s land of plenty descend into a perilous free-for-all? For over a thousand years, migrant farmers, pastoralists, and mineral-seekers have gravitated to the Albertine Rift Valley with high hopes that were invariably met. The first wave of Bantu immigrants some 2,500 years ago, “were running away from the Sahara desert and malaria in present-day Cameroon and Nigeria,” says Pierre Ruzirabwoba, director of Rwanda’s Institute of Research & Dialogue for Peace. “Then, several hundred years later, came a group of people from present-day Somalia and Ethiopia who were running away from conflict and overcrowded cattle pastures. When conflicts would arise over land, the Mwami’s deputies—one in charge of grassland, the other in charge of farmland—would make sure everyone had what was sufficient.”

Trouble arrived when the Europeans did, at the end of the 19th century. While permitting the Mwamis to continue their local governance, the colonizers were struck by the physical differences between the darker-skinned Bantu, or Hutu, majority and the taller, lighter-skinned Ethiopian descendants, or Tutsis. Imposing their own racial stereotypes on a region that had previously never distinguished by color, the German, Belgian, and French administrators deduced that the Tutsis were intellectually

superior to the Hutus. The former were therefore given plum government jobs, while the latter became soldiers and farmhands.

In 1932, Rwanda's Belgian occupiers officially codified a racial caste system—and, inevitably, racial hostilities that spilled over the borders into Burundi and the Congo—by handing out ID cards that designated about 15 percent of its subjects as Tutsis, 85 percent as Hutus, and a tiny fraction as Twa pygmies. By the time the colonizers departed as the countries gained independence in the early 1960s, recriminations had already led to ethnically-based killings of Tutsis, followed by retaliatory murders of Hutus. Today, tensions between those two groups continue to play out in the Congo.

But the genocide that occurred in Rwanda in 1994 was the result of more than Hutu-Tutsi ethnic hatred, fueled by politicians hungry for power. The latter years of the 20th century brought a sobering recognition that there was in fact NOT enough for everyone in the Albertine Rift Valley—and with that, catastrophe. An alarming rise in birth rates coincided with the collapse of the coffee and tea markets during the 1980's, leading to great deprivation; poverty led to even higher fertility rates, and thus to an even greater strain on the land. While it's true that many industrialized countries have population densities as high as Rwanda did at this time, they also have mechanized, high-yield agriculture that allows a few farmers to grow enough food for the whole country. In Rwanda's subsistence agricultural society, the only way to grow more food was to clear forests

with slash-and-burn agriculture.

By the mid-1980s, every acre of land outside the parks was already being farmed. Sons were inheriting increasingly smaller plots of land. Soils were depleted. Tensions were high. Belgian economists Catherine Andre and Jeanne-Philippe Platteau conducted a study of land disputes in one region in Rwanda both before and after the genocide and found that an increasing percentage of households were struggling to feed themselves on so little land. Interviewing residents after the genocide, it was not uncommon to hear Rwandans argue that "war is necessary to wipe out an excess of population and to bring numbers into line with the available land resources." Thomas Malthus, the famed British economist who posited that population growth would outstrip the planet's ability to sustain it, couldn't have put it more succinctly.

Platteau and Andre are not suggesting the genocide was an inevitable outcome of population pressures. The killings were clearly influenced by political decisions made by power-hungry politicians. But several scholars, including French historian Gerard Prunier are convinced that a scarcity of land set the stage for the mass killing. In short, the genocide gave landless Hutus the cover they needed to initiate class warfare. "At least part of the reason why it was carried out so thoroughly by the ordinary rank-and-file peasants was feeling that there were too many people on too little land," Prunier observed in The Rwanda Crisis, "and that with a reduction in their numbers, there would be more for the survivors."

The Eastern Congo Village of Shasha—roughly equidistant to Goma to the north, Bukavu to the south, Masisi to the west and Lake Kivu to the east—has become a grim crossroads for roving rebels seeking land, minerals, and revenge. Nearby mines holding eastern Congo's abundant tin, coltan, and gold are almost exclusively under the control of various armed groups—the Hutu and Tutsi paramilitaries, the Mai-Mai militias of the indigenous groups—each descending on Shasha village in a macabre rotation, one after another, month after month, in a wave of mayhem.

A woman named Faida weeps quietly as she recalls what happened to her a year ago. She is petite and ebony-skinned, with fatigued eyes and a voice just above a whisper. In her hands is a letter from her husband, announcing that he is divorcing her because he fears she might have contracted HIV from the men who raped her.

On that fateful day, Faida was on the same road she always took after working in the peanut fields some 40 miles southwest of Goma. She would walk an hour and a half to the market at Minova with the peanuts on her back; then return home with firewood on her back. Faida was 32 and of the Hunde tribe, married with six children, and for 16 years this had been her routine. She believed no one would attack a woman in broad daylight.

The three men were rebel Hutu. She tried to run, but the load on her back was heavy. The men instructed her to lay

down her bag. They told her to choose between life and death. Then they dragged her into a cattle field. She lost consciousness.

Today she lives with neighbors and cannot work. Her ex-husband quickly remarried. The damage done to her reproductive organs is extensive. “I’m really suffering,” she says. “Please help me get medication, I beg you.”

Shasha’s population is about ten thousand, twice what it was in 1994, and its story is, writ small, that of the eastern Congo. A Hunde stronghold since antiquity, Shasha began to receive Hutus in the 1930s, when the Belgian occupiers brought them in to work their coffee and tea plantations. Later, in the wake of the 1994 genocide, came thousands of Tutsi refugees. Land disputes became overheated and were frequently resolved at the point of the gun. The area’s vast mineral wealth only made things worse. Scarcity and abundance both exist here side by side, fueling grievances as well as greed, spiraling into inexplicable violence against innocents.

Goma women’s advocate Marie Gorette estimates that over eight hundred women in the village have been raped. They range in age, she says, from six months to eighty. Gorette offers to introduce me to the women of Shasha. And so one afternoon we sit in a village hut while the ladies enter one by one to tell their stories.

Odette is strong-shouldered and wears a blue print dress. It happened to her just ten days ago. Her 12-year old son found her unconscious in the cassava fields where she had been working.

Chantel is forty-two. Tutsi rebels barged into her house four years ago, took all the family's money and declared it was not enough. Her husband was forced to watch at gunpoint. Justine looks much younger than twenty-eight, with lively eyes. The Congolese Tutsi warlord Laurent Nkunda (now-imprisoned) brought his CNDP army into Shasha in 2008. Justine was far from the only one—many of her relatives and neighbors were raped as well.

In 2005, the UN estimated that some 45,000 women had been raped in the eastern province of South Kivu alone. And despite international attention following a 2009 visit to the region by U.S. Secretary of State Hillary Clinton, the abuse continues. Just as the "Hutu Power" Rwandans in 1994 sought to eradicate the Tutsis by deliberately massacring women and children, Shasha's invaders are human heat-seeking missiles aimed at the village's women. "Because it's the corridor, Shasha is the worst place in the region when it comes to mass rapes," says Gorette. "They use rape as a weapon to destroy a generation."

I am somewhere in Rwanda when my car breaks down. A man pulls over to where I'm hovering over the smoking engine and offers to drive me the remaining 70 or so miles to Kigali. "If this were the Congo, you would be in big trouble," he laughs.

The 41-year old man's name is Samuel, and though he is from the farming community of Romagana, his vocation

is carpentry. By the region's standards, Samuel's family is small—"only four children," he says. "I think that's the ideal size." Schools cost Samuel about four thousand dollars per child each term. "But I think education is the solution. Otherwise people have no work. They just resort to having lots of children and stealing to survive." The broad-faced man smiles and says, "I'm very optimistic about our country. The future is indeed bright."

It is no small miracle that the country where the Albertine Rift Valley's anxieties and resentments metastasized into genocide would, less than two decades later, emerge as the region's beacon of hope. Rwanda's president, Paul Kagame, drove out the Hutu leaders of the massacre and set up a minority Tutsi regime that has been in power ever since. Recently Kagame's luster has been tarnished as he's come under criticism for civil rights abuses against dissidents—and for using paramilitary groups to divert mineral riches from the eastern Congo. Though Rwanda has largely stopped the direct plunder of resources that occurred during Congo's last civil war, Kagame's plans to build up his country definitely depend on continuing to covertly exploit its neighbor's mineral wealth.

Still, in this neighborhood, there's no denying the long list of successes Kagame has piled up in an incredibly impoverished place. Rwanda is now one of the safest, most stable, and least corrupt countries in Africa. The roads are paved, the landscape is tidy, and cutting down so much as a single tree has been illegal since 2005. Government programs offer poachers alternative

livelihoods such as beekeeping. An event known as Kwita Izina has raised awareness of wildlife conservation with an annual ceremony to name every newborn mountain gorilla in Rwanda. A law passed this past January provides compensation for livestock killed by wildlife. An environmentally sensible regazzetting of Rwanda's Akagera National Park in 1997 gave hundreds of acres back to its citizens, while hundreds of additional acres owned by wealthy landowners in the country's eastern province were redistributed in 2007—though Kagame himself, and other influential cronies, continue to own sprawling estates.

Unlike in Uganda, where President Musevini has declared its high birth rate a tool in building a productive workforce, Rwanda is tackling its high fertility rate with an aggressive family planning campaign. "When I look at the problem of Rwanda's population, it starts with the high fertility rate among our poor women. And this impacts everything—the environment, the relationship between our people, and the country's development as a whole," says tktkt, the deputy speaker of Parliament. "For all the visible progress Rwanda is making, if we don't address this matter, then it will create a bottleneck, and our development will be unsustainable."

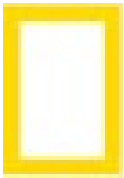
Yet even if Rwanda's fertility rate falls below replacement level, as it's projected to in 2050, its population will still double beyond what it was during the 1994 genocide. Forty-five per cent of Rwandans are under the age of fifteen; the same percentage are illiterate. Nearly

85 percent live in rural areas. To feed its burgeoning population, and protect the wildlife still left in its parks, Rwanda will need to figure out how to produce much more food on much less land—a tall order in this part of the world. Even Kagame's strongman government can only do so much so fast.

"The average family of six has little more than half an acre here," says Pierre Ruzirabwoba. "And of course, those children will have children. Where will they grow crops? That small piece of land has been overworked and is no longer fertile. I'm afraid another war could be around the corner."

Another full-scale war in the heart of the Albertine Rift Valley? It's an awful thing to contemplate. Ruzirabwoba fretfully ponders the way out. High-yield farming techniques, of course. Better job opportunities in the city. And "a good relationship with our neighboring countries."

Then he shrugs and says, "Perhaps some of our people can migrate to the Congo."



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