

## NEWS FEATURE:

# We are seven billion

Kerri Smith

This autumn, the world's human population will pass seven billion. Researchers are trying to identify the geographic hotspots where people and climate change are on a collision course.

When Mark Montgomery began his career in demography in the early 1980s, the world population hovered at around 4.8 billion people. There were already concerns about how the Earth's resources would stretch to sustain so many, but environment and population tended to be discussed separately. "People were struggling to make something of the population-environment connections," he says.

On 31 October 2011, according to projections made by the United Nations (UN), there will be seven billion people sharing the planet — at a time when the biota is under increasing pressure from climate change and other environmental threats. This unprecedented human number is not made of identical communities spread evenly around the globe (Box 1); likewise, climate change will not affect the planet's diverse environments in the same way or to the same degree. Some areas will be hit by the double whammy of a growing population and an increase in climate change impacts.

But where exactly are these areas — and who lives there? It might seem crazy, but right now it's difficult to answer this question. What's needed is fine-grain information about local landscapes and the demographic make-up of their inhabitants — and this information, startlingly, is either absent or, Montgomery says, it is languishing unanalysed.

Adaptation to climate change is already a big theme in the work done by the Intergovernmental Panel on Climate Change and others. But there's something missing from the population side of the equation, Montgomery says. "The global conversation about climate change has been fixated on emissions: their levels, who's responsible, what can be done to bring them down, and who'll pay," he says. There has been much less discussion about precisely who will be affected by the consequences.

To find out, you need to know much more than just how many people live in a particular country or municipal region. If a heatwave hits or a coastal region is threatened with flooding, you need data on



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Crowded times: India is expected to overtake China as the most populous nation by 2030.

where exactly your population lives, how old they are, what proportion are women and children and how much they earn — all this information can help estimate how many people are likely to be vulnerable or resilient to climate impacts. This is a job for demographers — and it might seem an obvious job. But so far, "adaptation has been done in a demographic vacuum," says Deborah Balk, who studies the interactions of population and climate at the City University of New York.

"In high-income countries, highly detailed, spatially specific population data are plentiful and easily available," says Montgomery. "That is not at all the case in poor countries. And it is in these countries that the consequences of global climate change will be most keenly felt." David Satterthwaite, a development planner at the International Institute for Environment and Development (IIED) in London, says that much of the information exists, but at the wrong scale. "Demographic and health surveys are nationally representative samples, so they can't tell you what's happening in smaller spatial units. If I'm planning investment, the surveys don't tell me anything about where services are needed."

Satterthwaite says that cities in high-income countries have a certain level of resilience to many climate impacts. London, for example, has adequate drainage and sanitation and good building standards. Londoners are able to buy insurance for property and possessions. But if no generic resistance exists, "then you've got to be much more sophisticated in targeting who's at risk, and understanding why and how they are at risk to determine how it can be reduced," he says.

To fill this yawning gap, Balk, Montgomery and others are starting to combine the kinds of data that demographers collect — population size, birth and death rates, migration and age structures — and overlapping them with spatial and geographic information to nail down where the risks of climate change might hit the hardest (Box 2).

This isn't something that's been achieved before; no single data set provides a synthesis of individuals and the communities — both social and geographic — in which they live. Adaptation work, explains Balk, is often on a case-by-case basis.

But when these data are pulled together, they can reveal emerging impact issues. Most of these issues concern cities. We are now a planet of seven billion; the UN predicts

**Box 1 | In numbers.****9.3 billion**

The number of people that will inhabit the planet by 2050, according to UN estimates.

**13%**

Of the world's population live in at-risk coastal areas (which make up 2% of the world's land area).

**75%**

Of people who live in at-risk coastal areas (0–10 m above sea level) are in Asia.

**68.7%**

Of the world's population will live in urban areas by 2050 (in 2010, this figure was 50.5%).

**21**

The number of megacities (cities with more than 10 million inhabitants), according to a recent UN estimate.

**7.19**

The 'total fertility rate' of Niger — the highest in 2009. This rate is the average number of children a woman would have at the end of her reproductive period if the current fertility rate of the country continued over that period.

**29,650**

The number of people per square kilometre in Mumbai, the world's most densely populated city. Second is Kolkata with 23,900 and third is Karachi with 18,900.

**10.58%**

The 2006–2020 growth rate of the world's fastest growing city, Beihai on the south coast of China. Second is Ghaziabad in New Delhi, India (5.20%) and third is Sana'a in Yemen (5.00%).

that by 2050 we will be nine billion. Most of that extra two billion will be in the cities and towns of lower-income countries. This isn't a reason to immediately panic. "Rapid population growth itself doesn't necessarily produce risk and vulnerability," Satterthwaite says. "Indeed, if it's concentrated in a city with a successful economy and a decent government, there are dramatic causal relationships between population growth and less vulnerability." But there are plenty of places around the world where the wealth or inclination to help those likely to be vulnerable to climate change doesn't exist.

In a recent report<sup>1</sup>, Balk gives some examples. One is China's coast, where cities

have been growing at double the rate of the population as a whole — 1.04% population growth between 1990 and 2000 versus 2.33% urban population growth over the same period — and many of the fastest-growing urban areas are on or near coastal zones, right at a time when climate change is predicted to increase the risk of extreme flooding and weather events such as cyclones<sup>2</sup>. More than 78 million people were living in urban areas in this low-elevation coastal zone in 2000, the most recent year for which such data exists. Finding ways of lessening the impact of climate change will depend on changing the country's economic strategy to deflect investment and trade away from the urban coast.

**The seething mass**

People and climate change are intricately linked, not least because humans are generating greenhouse-gas emissions that are warming the planet. But it's only recently that population size and growth have been explicitly factored into the emissions equation. In a study published last year<sup>3</sup>, Brian O'Neill and his colleagues at the US National Center for Atmospheric Research modelled the effects of demographic change on carbon dioxide emissions, and showed that slowing population growth could provide 16–29% of the emission reductions necessary by 2050 if we are to avoid dangerous climate change.

So far, models like this just cover the relationship of population growth to emission levels. But these models could soon help highlight some of these climate–population pressure points too.

O'Neill's work is already hinting at important factors adding to the brew. For example, his team is halfway through building a model that projects the rate at which people move to or are born in towns — the process of urbanization — for different countries. By 2050, it is estimated that almost 70% of the world's population will live in cities; up from 50% in 2010. This in turn, as Balk and Montgomery suggest, could dramatically affect the number of people affected by adverse climate events, if growing cities are positioned on the coast, on susceptible river deltas, or in arid areas that are predicted to become drier.

O'Neill's models aren't yet fine-tuned enough to use in determining what impacts will be felt in a particular location, but he says: "We are producing scenarios that have the kind of information you'd want to include to do those kind of assessments."

**Overlapping data**

O'Neill is talking about urbanization in quite abstract terms. Balk, Montgomery and

their colleagues are starting to ask similar questions at a more granular level. It's clear that to help cities adapt properly, scientists need to understand better "where populations live, neighbourhood by neighbourhood," says Montgomery. Balk has put together the winsomely named GRUMP dataset (the Global Rural–Urban Mapping Project), by collecting population data from regional censuses, information on land elevation from satellites and, to identify urban areas, looking for regions that are most lit-up at night.

Balk's team is starting to reveal the geographic regions of the planet where the most people are most at risk from climate change. In much of Asia, cities in low-lying coastal zones are growing faster than average. Cities in low-lying areas of the Mekong Delta in Vietnam — one of the most densely populated areas on Earth<sup>4</sup>, and already subject to frequent flooding — have five times more people living in poverty than cities outside this low-elevation zone<sup>5</sup>. Poorer people are considered at greater risk from climate impacts, because they are less able to adapt or move away. It's a similar story in Medan, Indonesia's third largest city, located at the confluence of two rivers on the Strait of Malacca on Sumatra's northern coast, where residents regularly experience inundation. Overlapping poverty data with satellite data yields a map that could help governments and organizations to respond appropriately to disaster by targeting the poorest communities with their interventions.

Asia is a flashpoint for flooding risk. It hosts about three-quarters of the world's population that falls into low-elevation zones, defined as 0–10 metres above sea level. In Asia, "one in ten people, and one out of every eight urban dwellers, live on the coast no more than ten metres above sea level, and that number is increasing," said Balk's colleague Gordon McGranahan. "People are running towards risk, particularly in China, but also in other parts of the world such as Bangladesh, where more than 40% of the land area is within ten metres above sea level."

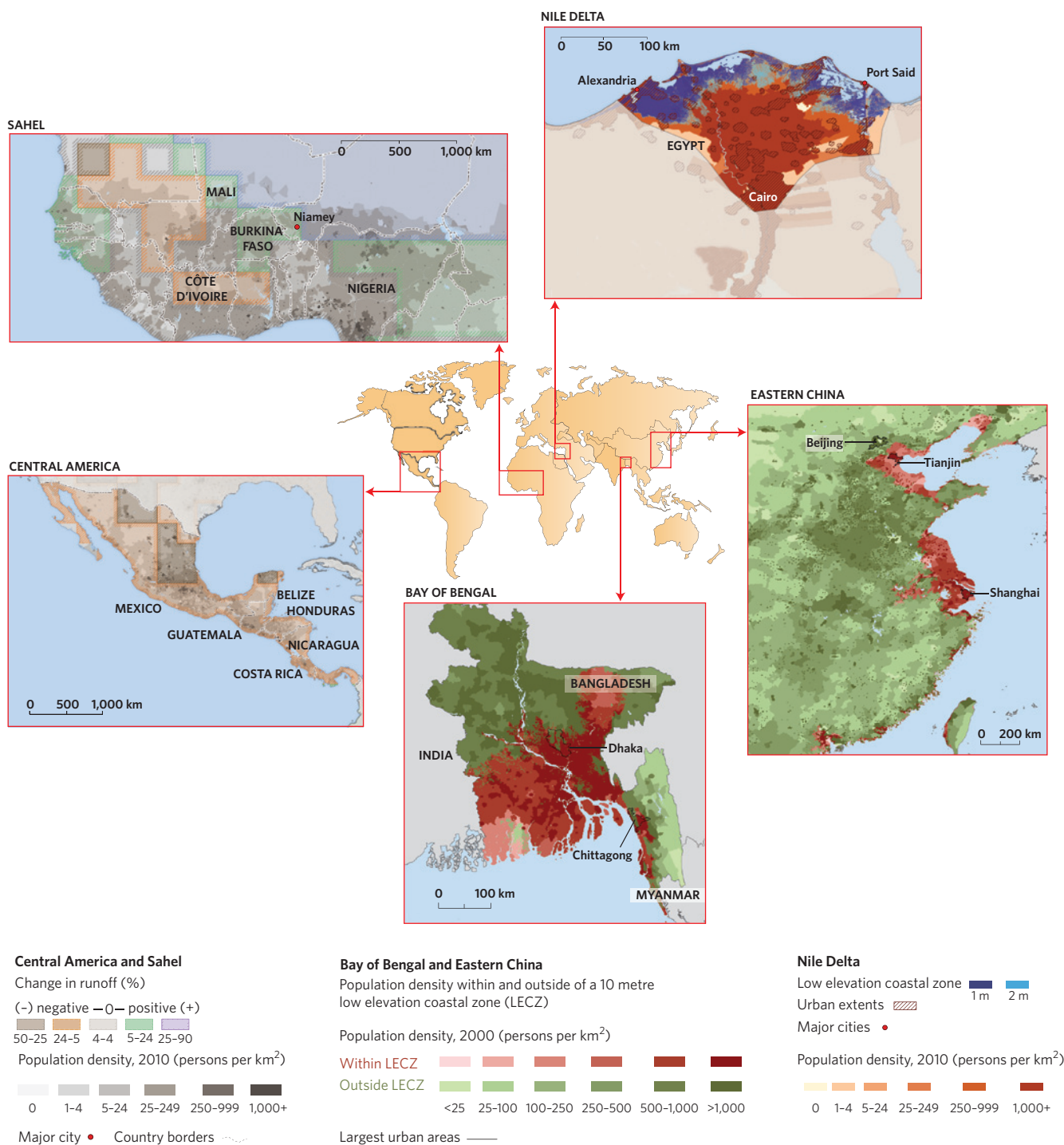
At the other end of the scale is water scarcity. Using the GRUMP dataset, a team led by Robert McDonald of the Nature Conservancy in Arlington, Virginia, and including Balk and Montgomery in its number, calculated that there are currently 150 million people living in cities with perennial water shortage, defined as under 100 litres per person per day<sup>6</sup>. By 2050, demographic growth alone will bump this figure up to almost one billion, and climate change will account for another 100 million people living without enough water. A separate analysis shows that drylands — characterized by low, erratic precipitation — are home to about half of Africa's urban

**Box 2 | Under pressure.**

Some parts of the world face a double whammy of population pressure and severe climate impacts, such as an increase in the severity of droughts or flooding. Researchers are beginning to

compile and analyse detailed demographic and geographic data for these places, which should help agencies plan adaptation strategies. Bay of Bengal, Central America, Sahel and Nile Delta

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Under water: climate change will bring increasingly severe floods to overcrowded coastal cities.

population, and in India the figures are even higher, with up to 67% of urban residents in drylands<sup>1</sup>. “The only positive note is that emerging water scarcity is not going to be an overnight phenomenon,” Montgomery says. “There will at least be some time to plan for alternative settlement patterns and means of water extraction that may help.”

Balk is now working on a version of their data updated with information on city growth and migration. Preliminary results suggest that West Africa is an area to watch. The countries here harbour cities that may not be anywhere near the world’s biggest, but they appear to be growing fast. For instance, eight of the ten countries with the highest projected urban growth rates for the next decade or so are in Africa, and include the West African nations of Burkina Faso and Niger<sup>7</sup>. The land that supports many of these cities is very arid, and many are in coastal regions with associated flood risks.

### Location, location, location

People are not stationary, and migration is another important ingredient in the population–climate interaction. Many demographic variables, such as birth and death rates, aren’t keenly affected by climate and take longer to change, but migration is faster, and it can cut two ways. Either people will move as a result of climate change in the home region, exacerbating pressure on nearby regions, or they will be unable to get away, and therefore suffer the local effects more heavily. “There’s a fair degree of controversy about the degree to which climate impacts might cause people to move,” says Alex de Sherbinin, of Columbia University’s Earth Institute in New York. He points out the ‘immobility paradox’, the idea that many people don’t have the resources

or the freedom to move — they may have relatives that need looking after, for example.

Estimates for how many people will be uprooted by climate change vary widely. The International Organisation for Migration estimates that by 2050, 200 million people will have been forced to migrate owing to environmental pressures. And climate change may also provoke conflict<sup>8</sup>, contributing to more migrations.

De Sherbinin’s team at Columbia is not alone in thinking about the consequences of population migration. Another project run by the UK government as part of the horizon-scanning Foresight programme is examining climate-induced migration, the results of which will be reported at the end of the year. The European Union also ran a project, which finished in 2009, called EACH-FOR (Environmental Change and Forced Migration Scenarios)<sup>9</sup>, which relied on a number of case studies to illustrate how climate was pushing people around.

A study published last year by Michael Oppenheimer and his team at Princeton University in New Jersey estimates the consequences of climate variations for crop yields in Mexico and, subsequently, migration away from affected areas. Oppenheimer’s study took data on the sensitivity of the Mexican population to past climate variability and extrapolated that into the future. With other factors — such as the political and economic situation — held constant, they projected that by about 2080, around 1.4–6.7 million Mexicans would emigrate as a result of declines in agricultural productivity<sup>10</sup>. “This would certainly be on a par with some of the largest migrations in recent years,” says Oppenheimer. “And it could be one of the largest in future.” The

team is now working on climate-migrant numbers for other regions around the world.

### Data in action

Data on where people are and the risks they face is one thing — reducing those risks and helping populations adapt is another. Montgomery is hopeful that his data could be useful quite quickly when floods or droughts hit. “There’s an international relief effort that gets mobilized when these events take place,” he points out. “If we look ahead a bit, we might imagine an alliance of institutions already doing disaster relief with social scientists providing them with information,” for example on where to go, who lives there and what characteristics make them vulnerable.

One focus of de Sherbinin’s recent work is how to plan for resettlement if people need to move. He helped run a workshop, held last year in Bellagio, Italy, which examined lessons from resettlement programs associated with dam-building or relocating people from land at risk of desertification, and attempted to apply them to the likely resettlements that climate change will cause. Previous resettlement programmes have been government-led and heavy-handed. De Sherbinin says that better consultation with local people would help ensure that their rights are upheld, when *in situ* adaptation no longer becomes feasible.

In some locations already feeling the impacts of climate change, local people have begun doing demography themselves. David Satterthwaite works with several groups living in informal settlements that perform their own equivalent of a census. In Cuttack, an Indian town bordered by two rivers and stricken with frequent floods, there are 331 informal settlements, often in areas most at risk. The group, part of an organization called the National Slum Dwellers Federation, went door-to-door, asking in-depth questions about when the last flood was, how high the water came, what people lost, and when they moved away and came back — as well as compiling basic census information about the number of people in each house, how old they were and what gender.

This information was linked to geography by GPS devices carried by the census-takers, providing the people of Cuttack’s informal settlements with the means to go to their municipal government for adaptation help. Initiatives like this one have sprung up in the Philippines and several southern African nations too, according to Satterthwaite. “When I work with the federations I come away stunned and amazed at their resilience, their creativity, their humour and their capacity,” he says. But these are small pockets. “I look at the big picture and I go ‘oh. Local

governments are going to have most of the responsibility for building resilience and vulnerability reduction. They have to work with those who are at risk. Most are incapable of doing so or choose not to do so.”

One thing we must not forget is that our population situation could be much worse, says Hania Zlotnik, director of the Population Division at the UN Department of Economic and Social Affairs. Family planning programmes around the world have helped birth rates to fall much more quickly than if left to their own devices. “We could have ten billion, and we only have seven,” she says. “If there’s an area where there has been incredible success, it’s population.”

But even though ours could have been a more crowded planet, our current running total of seven billion is still a formidable number. “Providing resources for those people to live well is already a challenge,” says Zlotnik.

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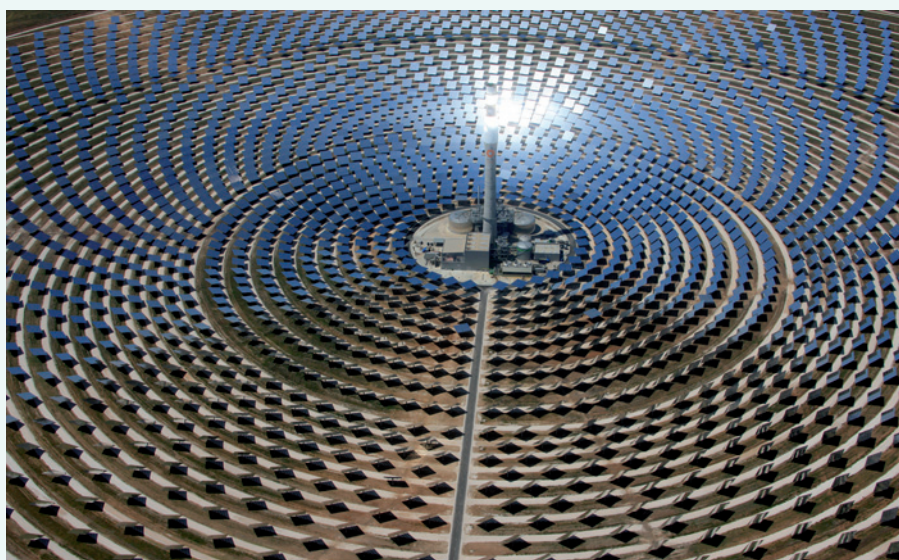
## SNAPSHOT

# A diamond in the rough

The first solar power plant that is capable of providing uninterrupted electricity generation throughout the day and night has started to supply the Spanish grid from a location near Seville, in Andalusia.

The Gemasolar plant jumps out of its semi-arid farmland surroundings like a giant patch of sequins. It is composed of a central tower, standing at 140 metres tall, and 185-hectare field of 2,650 carefully arranged flat mirrors, known as heliosats. These focus the Sun’s rays onto a receiver at the top of the tower. Nitrate, pumped up the tower from a tank, circulates inside the receiver, where it is heated quickly and intensely to 565 °C, before being sent to the plant’s hot storage tank. When the grid demands power, nitrate in the hot storage tank is pumped to a heat exchanger, which, as in traditional power stations, generates steam that turns a turbine, and produces electricity.

This system can supply continuous power for 15 hours after the Sun has set on a summer day. Furthermore, it produces a more even supply of power than photovoltaic solar cells — the effect on power output of a large, dark cloud that obscures the Sun is both damped down and delayed for between 6 and 15 hours. Most solar plants heat oil, which doesn’t get as hot as nitrate, so they can’t generate as much after-dark energy. Gemasolar’s output, however, can be varied according to the regional grid demand, which peaks shortly after sunset, says Oihana Casas, spokesperson for SENER engineering group, majority shareholder of Torresol Energy, which owns Gemasolar.



Gemasolar’s 19.9 MW turbine is expected to meet the electricity needs of 25,000 Spanish households through the substation of Villanueva del Rey. Were the same amount of energy to be produced by burning fossil fuels, 218,000 barrels of crude oil or 38,600 tons of lignite (low-grade coal) per year would be needed, emitting 30,000 tons of carbon dioxide.

Similar projects to Gemasolar are in the pipeline, but most are planned for the western United States where renewable-portfolio-standard targets have strongly encouraged utility companies to sign deals with solar developers.

In October 2010, a company called BrightSource Energy, based in Oakland,

California, started building a solar plant about five miles from California’s border with Nevada, in the Mojave Desert, that will make Gemasolar look puny. Ivanpah One, as the plant is known, will have 173,000 heliosats and supply 140,000 homes. BrightSource has even more ambitious plans for a 3,277-hectare patch of land 45 miles west of Las Vegas, Nevada. There, CEO John Woolard says he wants to build a truly massive central tower, almost 230 metres high, and create a solar plant with twice the power-generation capacity of Ivanpah One.

ANNA PETHERICK

**Correction**

In the News Feature 'We are seven billion' (*Nature Clim. Change* **1**, 331-335; 2011), CIESIN should have been included in the credits for the panels in Box 2. Corrected in the HTML and PDF versions after print, 30 September 2011.