The tree counter

Geographer* Matthew Hansen *is creating real-time maps that show where forests are being destroyed. Not everyone believes them.

BY GABRIEL POPKIN

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Ask Matthew Hansen to show off his data and he hunches over his computer like a possessed video gamer. With a few mouse clicks, he flies over the globe and zooms in on a forest in Indonesia. The area is designated as a preserve — supposedly protected from deforestation — but Hansen's data reveal a different reality. Bird's-eye images of the trees taken every eight days flash by on the screen. At first, a few red spots perforate the green canopy around the preserve's edge. Then they spread, like bloodstains. "That's got to be illegal fires," he says. "The forest is getting chewed up."

Hansen is among the world's foremost forest sentries. In 2013, he and his colleagues used satellite data to produce the first global, high-resolution maps of where trees are growing and disappearing[1]. Those images revealed some large-scale patterns for the first time, such as that Indonesia had nearly equalled Brazil as the country with the world's highest rate of tropical deforestation. Since then, his team has refined its methods and can now reveal the loss of trees within days.

Just as important is what Hansen does with the underlying data. Unlike some scientists, he makes them freely available online, giving activists, companies and others the ability to monitor activities such as illegal logging and mining, which have destroyed millions of hectares of forest per year over the past few decades. The data have enabled non-governmental organizations (NGOs) and officials in Peru, Congo and other nations to see deforestation as it happens. And they let countries monitor each other's trees — potentially a crucial step in enforcing the international climate agreement signed in Paris last December.

But some have argued that the maps do not always work as advertised. For instance, they lump together destruction of natural forests and the harvesting of managed ones, which critics say leads to inflated estimates of deforestation. And others question whether satellites can monitor forest loss and growth accurately enough to determine how well countries are complying with their commitments on climate change and deforestation, including the Paris deal.

One thing no one disputes is that Hansen is showing the world how mapping from the sky can have an impact on the ground. "If you want to know what's up, you look at what Matt's doing," says Martin Herold, a remote-sensing expert at Wageningen University in the Netherlands. "Nobody's even close."

WANDERING START

Hansen instantly disarms people with his down-to-earth nature. On an unseasonably warm day earlier this year, he was wearing shorts and a short-sleeved shirt when his assistant reminded him that he was due at a meeting. "I'm not dressed for that at all," he laughed as he set off across the campus of the University of Maryland in College Park. His informality helps when working with both African farmers and Hollywood actors, with whom he mingles as easily as with other scientists and policy wonks. But beneath the casual exterior is an intensity that has made Hansen one of the world's most sought-after experts on forests.

Growing up in Indiana surrounded by farm fields, Hansen did not spend a lot of time among trees. But he was struck by trips to the state's few remaining patches of original hardwood forest, which reminded him of Lothlórien, the sylvan kingdom of the elves in *The Lord of the Rings*. He studied electrical engineering at university and then was accepted into law school, but neither stoked his passion. What did excite him was adventure, and he got plenty of it when he headed to what was then Zaire (now the Democratic Republic of the Congo) to volunteer with the Peace Corps.

But when he returned, he still had no clear career direction. "I came back and I thought, what do I like? I like maps," he says. So he went to the University of North Carolina in Charlotte for master's degrees in geography and civil engineering. He took a job at the University of Maryland in 1994 and has been mapping land-cover change using satellite data ever since, picking up a PhD in 2002.

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Hansen has pursued a single goal: to map global land cover with the highest possible resolution using cheap or free data, to better visualize the human footprint on the planet. He has specialized in writing programs to identify diverse types of vegetation — from boreal conifers to palm plantations — using the handful of light frequencies that satellite sensors collect. "He's an exceptionally good geographer," says long-time colleague Thomas Loveland of the US Geological Survey in Sioux Falls, South Dakota. "He really has an understanding of what this planet's made of."

Hansen and his colleagues also meticulously 'ground-truth' their maps by picking random samples of GPS points and getting to them by any means necessary. "It's his favourite type of vacation, to throw random points on ground and go visit them," says his postdoc Alexandra Tyukavina.

In the mid-1990s, when Hansen was starting, the best information about tree cover came from country-level ground-based assessments, in which crews measured individual trees in representative plots and then extrapolated across large regions. Such measurements were — and still are — used alongside remote-sensing data by the Food and Agriculture Organization of the United Nations (FAO) in its periodic global forest assessments. But many countries lack the resources to conduct regular surveys, and others publish statistics that seem unreliable. So Hansen set his sights on producing what he calls a "globally consistent, locally relevant product" from data available to everyone in the world.

But first he had to wait for technology — sensors in space and computer processing power on the ground — to catch up. The first global land-cover map from the University of Maryland came out[2] in 1994, using data from the Advanced Very High Resolution Radiometer (one of a series of orbiting imagers operated by the US National Oceanic and Atmospheric Administration). It had enormous pixels of one degree latitude by one degree longitude, much too coarse to make out details of forests.

A big step forward came when NASA launched its two Moderate Resolution Imaging Spectroradiometer (MODIS) instruments, which gather data at a resolution of up to 250 metres. In 2008, Hansen and his colleagues produced a map[3] that started to reveal large-scale trends in the tropics, such as that nearly half of widespread humid tropical-forest loss between 2000 and 2005 occurred in Brazil. Around that time, scientists working for both the Brazilian government and local NGOs used MODIS and other data sources to develop their own maps and issue alerts when large clearings appeared. This helped officials to use financial pressure, law enforcement and other means to dramatically reduce deforestation in the Amazon, the world's largest and most carbon-rich tropical-forest region.

That success inspired Hansen. But in many other tropical countries, rising consumer demand for commodities such as cattle, soya beans and palm oil has created powerful incentives to clear tropical forests. And in poorer countries, where heavy tree-felling equipment is rare and clearings tend to be small, MODIS's blocky images have proved less useful. Hansen knew that he needed to make his maps sharp enough to show roads snaking their way into previously untouched forests — an almost universal harbinger of larger clear-cutting. "We had to push the spatial resolution because we're interested in humans," he says.

In fact, the data that he needed already existed. Since 1972, Landsat satellites had been collecting images of Earth's surface, starting at a resolution of 80 by 80 metres per pixel and improving to 30 metres in 1982 — roughly the size of two basketball courts side-by-side. But those images had to be bought individually, at costs from hundreds to thousands of dollars each — much too expensive for a global study.

That changed in 2008, when the US government made all Landsat images free, including 3.6 million archived ones. Hansen immediately began making 30-metre-resolution maps showing how tree cover was changing in regions of interest, such as Indonesia and parts of Russia.

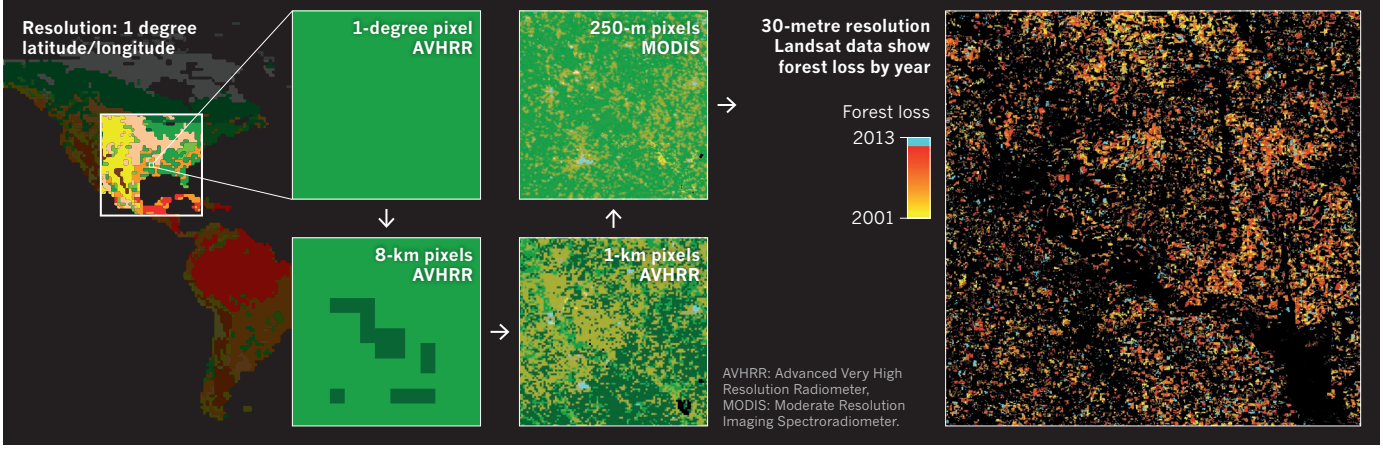
But making a global map still required processing power out of reach of any university computer cluster. A solution appeared when Hansen met Google engineer Rebecca Moore at a conference in Brazil. Moore was looking for scientists to try out her Earth Engine, a platform to analyse remote-sensing data using Google's cloud-computing capabilities. Hansen and Moore's teams processed the Landsat archive back to 2000 and translated it into annually updated maps that anybody with a computer and an Internet connection could view. "Matt was the first scientist who really leapt onto the platform with a global-scale analysis," Moore says.

In 2013, Hansen, Moore, Loveland and others published[1] their results in *Science,* showing where trees had appeared or disappeared every year from 2000 to 2012. The maps lit up the research community, which for the first time could see the world's forests shift in one consistent picture (see 'Better eyesight in space'). The fact that Hansen put his raw data on the web for others to scrutinize and use has also drawn admiration.

But it didn't take long for the critics to chime in. Many have objected to

BETTER EYESIGHT IN SPACE

Over the past two decades, Matthew Hansen and his colleagues have used satellite data with successively better resolution to map forests in increasingly fine detail.



SOURCE: M. C. HANSEN

Hansen's use of 'forest', which he defines to include oil-palm plantations and agroforestry, categories not included in FAO data sets. That made his deforestation estimates higher than many previous ones, such as the FAO's. The widespread publicity has further stoked concerns that non-experts are ill-equipped to interpret the data. "I personally think the data set was in some sense oversold," says Herold.

Hansen's visibility added to the scientific scrutiny. On the day that his *Science* paper was published, for example, he was in California showing his maps to actor Harrison Ford in a scene filmed for the 2014 US television series 'Years of Living Dangerously'. Ford later confronted Indonesia's forestry minister with some of the findings.

Other concerns have emerged. Some drier forests, such as those in parts of Africa and South America, have relatively sparse tree cover and might never reach the threshold that Hansen uses to define forest, which is that 30% of a pixel is occupied by vegetation at least 5 metres tall. So when those areas are cleared, the change might not register as forest loss, says Peter Holmgren, director of the Center for International Forestry Research in Bogor, Indonesia. Satellites struggle even more to capture forest gain, he adds, because the signal from growing trees is subtler than that of trees falling. For these and other reasons, he has warned against using Hansen's data to assess progress towards international climate and deforestation commitments, arguing that nations should instead invest in on-the-ground monitoring systems.

Hansen acknowledges that his maps do not supply everything. "You can't fit everybody's needs," he says. But his team is working to add data and make improvements that will show what activities are causing forests to change, and will differentiate plantations from natural forests. "That's what we have to do next, to make it more valuable."

Some of the objections have been more political. Hansen's map was particularly embarrassing for Indonesia because it came out during the 2013 UN climate talks, and revealed that deforestation rates in the country had spiked after a 2011 moratorium on new logging permits was announced. Indonesia's forestry ministry countered that Hansen and his colleagues were including large areas that the government had designated as plantation, unfairly overstating the deforestation.

Hansen's group responded the following year with a more sophisticated analysis[4], which confirmed that, in 2012, more primary tropical forest had fallen in Indonesia than in any other country.

For Hansen, the country's refusal to come clean about its forests is frustrating. But increasing transparency will take time, says Belinda Margono, a scientist with the Indonesian Ministry of Forestry who earned her PhD with Hansen and led the follow-up study by his group. She says that the maps have already helped to set that shift in motion, by promoting a culture of data sharing and openness, and by creating pressure to respond. "Sometimes the government has more courage to release the data after they see what's reported by the global system."

Larger forces are also at work. Nations and corporations are under increasing pressure to show that they are conserving forest to meet commitments under the Paris agreement or in sustainability-certification programmes for products such as palm oil. Since his 2013 paper, Hansen has become a globe-trotting door-to-door salesman of sorts, hawking his maps to forest ministers, corporate accountability officers, NGOs and others who need to keep an eye on forests.

IMMORTALIZED DATA

As almost 200 nations were hammering out the climate deal in Paris last December, Hansen was nearby, receiving a glowing introduction before he spoke at an environmental conference. "Matt and his team ushered in really a new era of measuring deforestation," said Frances Seymour, a forest-policy researcher at the Center for Global Development in Washington DC. "He's now immortalized because everybody talks about the Matt Hansen data on tree-cover change."

Hansen is now working to push his technique even further. Inspired by Brazil's alerts, he has begun processing and displaying data on tree loss as it happens in Peru, Congo, parts of Indonesia and Brazil. In the few months since the alerts went public, Peruvian environmental ministry personnel have used them to expose and shut down an illegal gold-mining operation. The alerts' very existence can have an impact, says remote-sensing scientist Fred Stolle of the World Resources Institute in Washington DC, which is releasing them weekly on its Global Forest Watch online platform. "People know now that they can be seen from space."

Hansen hopes to expand his alerts to the whole tropics by the end of the year, and later to cover the globe. The European Space Agency's Sentinel-2 satellites, which will collect data starting next year with a resolution of up to 10 metres, will enable him to update even more frequently.

Between the travel and the research, Hansen keeps a hectic schedule. But on a rare quiet afternoon, he can explore the world's forests from his desk on the edge of the Maryland campus. As he pans over Peru, a sea of green gives way to a rectangular island of pink that has grown during the past two years. "Someone went out there and clear-cut that," he says.

The view that Hansen has opened up, of trees falling all over the world, does not always reflect the best in people. "It's fucking alarming," he says. "The human footprint is amazing. We are a rapacious species."

But making that view available to everyone, he says, could help to rein our species in. "I hope it will bring some order to the chaos." ■

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