Running out of land

Alan Belward explains how satellites can help monitor the latest threat to life on Earth: a lack of space

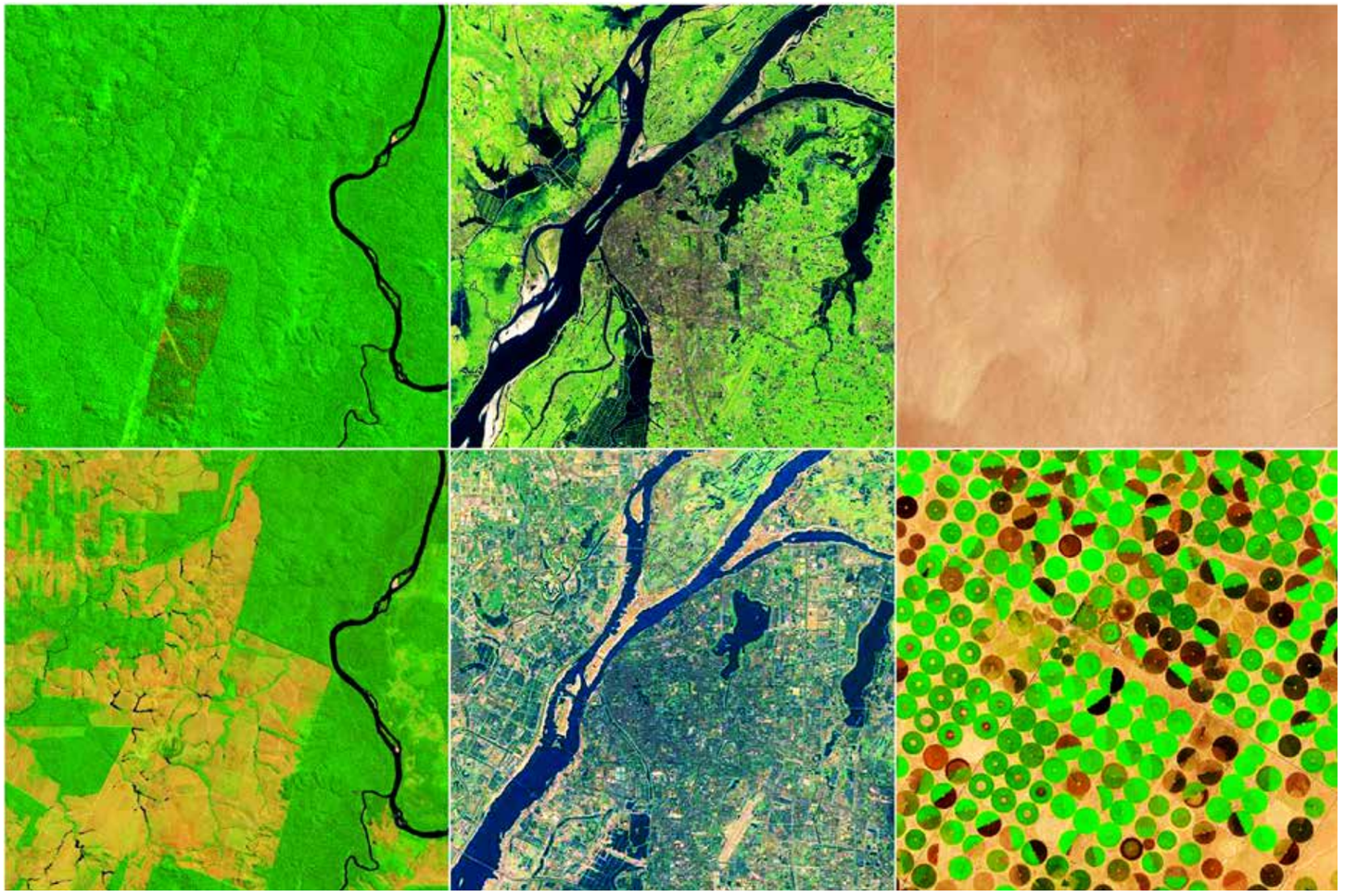
A soy field encroaching on the Brazilian rainforest

In 2011, the human population passed seven billion. Since then, according to the latest United Nations figures, this number has increased by approximately 155 people every minute[1].

Less than a third of Earth's surface is land, but this is where most of us live. A good fifth of this is either desert or permanently under snow and ice. Only 18% of the land has soils that are free of significant natural constraints for sustained crop production, yet we rely on it for around 99% of our calories[2]. By 2050, we are going to have to produce 70% more food than today[3].

Land does not just house us and feed us, it also provides essential fibre resources, bioenergy, shapes our planet's climate, is a major reservoir for biological diversity and a vital regulator in the hydrological cycle. Meeting all these needs, with what is essentially a non-renewable resource, is leading to intense competition between uses.

Information on land use is economically important, strategically valuable and sensitive as well. As such, it tends to be gathered and guarded by individual sovereign states. Land resource information is usually collected through surveys on the ground and from the air; photography and manned flight developed around the same time, and by 1858 photography from balloons was being used for land cadastres. Aircraft soon replaced balloons (and the use of miniature clockwork cameras on the Bavarian Pigeon Corps), and a little over a century after the first imaging efforts of



LANDSAT COURTESY NASA/USGS

THE COMPETITION FOR LAND
Illustrating 30 years of change, from the 1980s (top row) to today (bottom row). Left to right: conversion of forest to agriculture in Rondonia, Brazil (4th August 1984 to 4th August 2013); urban expansion Nanchang, China (15th July 1989 to 25th January 2014); desert to cropland Al Jouf, Saudi Arabia (26th October 1984 to 30th January 2014). All image tiles 300 km^2, North orientation

LAND USE: STRIKING A BALANCE

Increasing food production around the globe has created predictable changes to our planet's appearance, such as the replacement of forests with cattle ranches, and unexpected ones, such as circular wheat fields in hot deserts.

Since the 1980s, tens of thousands of circular 50ha fields have replaced swathes of bright, smooth, dry, desert with dark, rough, wet, photosynthesising cropland – you can see them by zooming in on the Arabian Peninsula on Google Maps (also pictured above). Each field uses at least 53 cubic metres of water per hectare per day to grow wheat, and almost double that for forage crops such as alfalfa.

Changing one component in the land system such as land use can affect others such as soil quality or biodiversity. Land use management plans, which aim to keep use and regenerative capacity in balance, stand the best chance of success if they are based on sound information concerning how, when and where land resources are being used, what condition they are in and how this is changing. Such information is economically important, strategically valuable and sensitive, and has legal ramifications in the context of environmental treaties such as the United Nations Framework Convention on Climate Change.

balloonists, satellites began collecting images of Earth from space.

Satellites provide the most comprehensive views of our planet possible – you don't need permission to fly over someone else's territory in space. The imaging capabilities from space provide new dimensions to our understanding of land resources, as we can now monitor changes in forest cover on fine scales (down to individual trees in some cases).

By the end of 2013, at least 34 governments and geopolitical groups had funded and/or licensed the successful launch and operation of almost 200 satellites with the potential to gather global land cover observations – and half of these are working today[4].

The European Union is just beginning its first ever Earth Observation programme, Copernicus[5], and this includes six advanced imaging satellites (the Sentinels), the first of which was successfully launched on 3rd April 2014.

Google's engineers have even set themselves the task of mapping every tree on the planet, but they'll need to be quick. The most recent satellite-based assessments of global deforestation indicate net annual loss of around 1.5 million hectares[6], the equivalent of losing a football pitch sized area of trees every two seconds or so. A proportion of this loss is due to natural fires, insect attacks and wind damage, but most is because someone considers the land more valuable when it has been cleared for ranching, plantations, cropping, mining, urban expansion, paper production, lumber or woodfuel than it ever was when covered by natural forest.

The Convention on Biological Diversity's (CBD) 2010 targets underline the need to halve the rate of loss of natural habitats, including forest, and to increase the existing protected areas from 12% of the land surface to 17%. However, with agricultural land in huge demand, where is the extra 5% for protected areas going to be found?

> **We lose a football pitch sized area of trees every two seconds**

The burning question

A systematic sample of satellite imagery across sub-Saharan Africa has shown that around 5 million hectares of natural vegetation are converted to agriculture or degraded every year[7]. With an estimated 2 billion people relying on woodfuel for energy[8], halving the rate of loss of natural habitats is challenging.

Charcoal is the fuel of choice (often from necessity) in most of Africa's rapidly growing cities and the growth in urban population is directly linked to increasing deforestation rates, particularly in proximity to urban centres and road networks[9]. Urban living is also becoming more popular and increasingly eating up other land. Nanchang in central China, for example, is expanding at rates of over 25km^2 a year[10].

It is not just emerging economic giants, either. The European Union loses around 1,000km of agricultural land to urban expansion each year, and in the last 16 years, this land would have produced over 6.1 million tonnes of wheat every year[11]. We do not only lose the land to produce food, we lose the food producers, too: migration from rural areas is a major factor in the expansion of cities. This means fewer farmers, which can lead to land abandonment and degradation.

The evidence from Earth-observing satellites so far points solely in one direction: human beings are running out of land. Mark Twain's assertion "buy land, they're not making it any more" is fundamentally correct; land should be considered a non-renewable resource. Land reclamation schemes provide some gains, but these are fractional on the global scale and can be dramatically reversed – just look at the impact of the 2013-14 winter on the Somerset levels. A tiny percentage of the world's coastlines are protected, yet sea level rise and storm surges cause land loss year on year. We should not stop land reclamation and protection schemes, but neither of these is a standalone solution.

So we need to optimise the use of what we have. Housing and transport infrastructure will continue consuming land. There are exceptions where urbanisation does not take land from other uses, such as Dubai's remarkable artificial coastline, but these are rare. Vertical living and use of brownfield sites should take precedence over sealing up good soil; the inevitability of urban spread and more roads needs to be questioned.

Growing more food per unit area is also fundamental. High rise greenhouses (vertical farming) have been mooted, but not implemented. Basically, we need to produce more from the fields we have.

Biology and technology are part of the answer, building drought and heat tolerance, disease resistance and nitrogen-use efficiency into plant selection. Precision agriculture, better irrigation and reducing soil compaction can also help, while improving land management practices can also increase yields.

Politics has a role, too. Administration systems that secure

BIOGRAPHY

Alan Belward tracks changes to Earth's land use at the European Commission's Institute for Environment and Sustainability, Italy, where he heads the Land Resource Management Unit. He studied plant biology at University of Newcastle upon Tyne, followed by a PhD in remote sensing studies of vegetation.

Deforestation in the Amazon rainforest

land allocation and rights of use for communities go hand in hand with stewardship and improved productivity; asset holders have a greater incentive to invest in their land, improve it and conserve resources[12]. Financial support systems are also required, as farming is highly susceptible to climate extremes, disease, even social unrest, and poor years can lead to land abandonment.

The reliance on woodfuels will not be broken in the short or even mid term. This off-grid source was humankind's first choice, and still remains the dominant renewable energy; non-woody biomass such as animal dung and grass are marginal in comparison.

Liquid fuels from biomass and biogas can help a nation's energy budgets, yet encourage the removal of land from food production. Second-generation biofuels, such as discard from food processing (pips and husks), should be encouraged, and major effort is required to develop and distribute stoves that burn woodfuels more efficiently.

Protection racket

Sometimes there is no alternative but to protect, and a dedicated policy push is needed for this. The food crisis of 2007 and the 2008 economic downturn drew the value of land into sharp focus. Land is currently less attractive in monetary terms when used for climate services (for example, carbon trading) and biodiversity than for competing land uses. Plantation crops of equal biomass might replace the carbon sink of a natural forest, but the emissions from the initial land cover conversion have already boosted atmospheric CO_2 levels. And species extinction is always irreversible.

Ecosystem restoration projects may occasionally rehabilitate diversity, but conservation and protection remain crucial for megafauna and complex ecosystems such as tropical forests. Policies designed to preserve and protect land for their biodiversity and role in the climate system are indispensable – without them these land uses will be out competed.

There are positive signs that such policies are emerging, but we should not be complacent.

Achieving balance in the global land use marketplace is in all our interests: for a climate we can tolerate for our planet's biodiversity and for our long term prosperity and survival.

If we share our scientific know-how, establish and follow meaningful land policies, address cultural attitudes to waste and consumption, and act together, then this is probably achievable. But we are already running out of land. The time for commitment, cooperation and action to address this new global challenge is now.

Land in Brazil cleared for cattle

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