Global Change

International Geosphere-Biosphere Programme

Issue 77 ▮ July 2011

TIMBER!
Fall of Rome etched in rings?

Politically Incorrect
Beyond the hockey stick

Anthropocene
Humanity claims geological status

GLOBAL CHANGE IGBP International Geosphere-Biosphere Programme

www.igbp.net
Earth-system science for a sustainable planet

ICSU International Council for Science

Contents

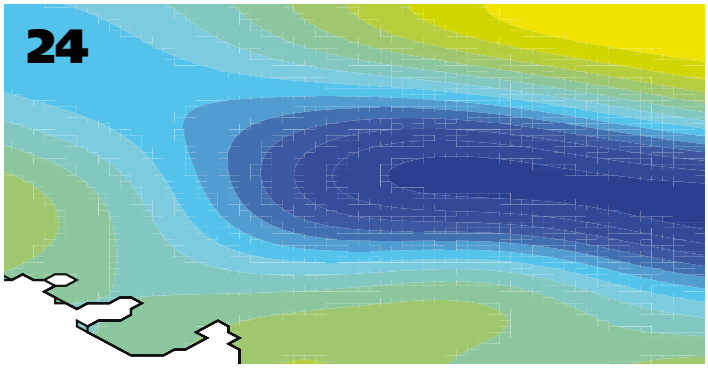
Cover image

Tree rings are valuable tools for reconstructing past climates. New data for Central Europe provide a record of climate change over the past 2500 years. They also reveal synchronies with important historical events. The cover depicts a cross-section through the trunk of a *Laburnum sp.* tree of the family *Leguminosae*. Photo credit: Sheila Terry, Science Photo Library/IBL Bildbyrå.

REGULARS

COVER STORY

FEATURES



Global Change primarily publishes articles reporting science from within the extensive IGBP network.

Published by:
IGBP Secretariat,
The Royal Swedish Academy of Sciences
Box 50005, SE-104 05, Stockholm, SWEDEN

To subscribe, unsubscribe or change your details email: charlottew@igbp.kva.se

Printed by Bergs Grafiska, Sweden

ISSN 0284-5865

Circulation: 7 000 copies

If you have an idea for a feature article or news, email Ninad Bondre.
ninad.bondre@igbp.kva.se

Editor: Ninad Bondre
ninad.bondre@igbp.kva.se

Director of Communications: Owen Gaffney
owen.gaffney@igbp.kva.se

Graphic Designer: Hilarie Cutler
hilarie@igbp.kva.se

Editorial

Sybil Seitzinger, Executive Director, IGBP

In the past few months, we have witnessed a growing interest in the concept of the Anthropocene – the age dominated by mankind. Momentum is building to officially declare it a new geological epoch. Editorials and articles in high-profile outlets such as *Nature*, the *New York Times* and *The Economist* have discussed the relative merits and demerits of recognising a brand new epoch. And the Anthropocene was central to discussions during the Nobel Symposium in Stockholm in May this year.

This is a good occasion to remind ourselves of IGBP's central role in promoting the type of thinking that first congealed around the term "Anthropocene". In fact, it was in the May 2000 issue of this very magazine (then known as the *Global Change Newsletter*) that the term was first coined by Nobel Laureate – and former IGBP Vice Chair – Paul Crutzen and Eugene Stoermer. Humans have had such a profound influence on the planet at all scales since the latter part of the 18th century, they argued, that the conceptualisation of a new, post-Holocene epoch was warranted.

It is now established wisdom that humans are the prime drivers of change on Earth, and it is this recognition that underpins the discussion of the Anthropocene. But it took decades of meticulous research to elucidate and quantify human impacts on the planet. Moreover, it took vision and creativity to connect what could have remained as disparate pieces of information (for example, the Great Acceleration graphs from IGBP's first synthesis). IGBP's contribution to the research, but equally or perhaps even more importantly, synthesising knowledge cannot be underestimated.

Synthesis continues to remain high on our agenda. During the past six months, IGBP has brought together natural and social scientists, policymakers, funders and others to synthesise knowledge about several policy-relevant areas, from geoengineering to nitrogen and climate (see page 4 of this issue).

Outcomes of this effort will find their way to the Planet Under Pressure conference to be held in London next year, and will also be consolidated as journal articles, opinion pieces and summaries for policymakers. The emphasis of the synthesis, as of the conference, is on solutions to move humanity onto a sustainable pathway.

Here's hoping that our efforts will yet again nourish the emergence of a concept as thought provoking as the Anthropocene.

> "Synthesis continues to remain high on our agenda.

Workshop discusses ecosystem impacts of geoengineering

ALTHOUGH several geoengineering schemes have been discussed with respect to their capacity to combat harmful climate change, their potential unintended consequences have received less attention. Against this backdrop, a diverse group met in La Jolla, California, for an IGBP synthesis workshop to explore the impacts of proposed geoengineering schemes on ecosystems.

The participants agreed that the key question is whether impacts of geoengineering methods would be less or more acceptable than the ecosystem impacts of the climate change expected for doubled CO_2. Research on the possible ecological impacts of geoengineering will be important, say the group, because geoengineering may produce new environments that differ from those existing in the present or produced in a non-geoengineered future. This research could be complementary to that needed and already under way on the ecosystem-impacts of climate change.
http://aerosol.ucsd.edu/IGBPworkshop

Ocean fertilisation summary published

Geoengineering schemes involving ocean fertilisation to affect climate have a low chance of success, according to the first summary for policymakers on the issue. The summary commissioned by the Intergovernmental Oceanographic Commission (IOC) was produced by the Surface Ocean Lower Atmosphere Study (SOLAS).
http://unesdoc.unesco.org/images/0019/001906/190674e.pdf

© Stock.xchng/ Kym McLeod

LINK BETWEEN NITROGEN AND CLIMATE PROBED

Human perturbations of the nitrogen cycle cause adverse health and environmental effects but might have a positive impact on Earth's climate (small net cooling) suggests a synthesis of recent work initiated by IGBP. There are many complicating factors, however, and the report resulting from this activity points out that current knowledge is insufficient to fully quantify the complex links between nitrogen and climate.

During pre-industrial times, the nitrogen and carbon cycles were in a state of equilibrium. But since humans began converting atmospheric nitrogen into reactive forms to make fertilisers, the nitrogen cycle has been profoundly altered. An effect on the carbon cycle, and thus climate, was to be expected. The direct effects include warming due to the release of nitrous oxide, a potent greenhouse gas, whereas indirect effects include stimulating the growth of terrestrial vegetation that sequesters carbon, thereby causing cooling. A key challenge is to quantitatively evaluate whether the overall effect is one of warming or cooling, says the report.

The findings of the IGBP synthesis will be discussed further at a workshop to be held later this year involving the Intergovernmental Panel on Climate Change (IPCC) and the Task Force on Reactive Nitrogen.

Planet Under Pressure: the Great Debate on five continents

IGBP's Director of Communications, Owen Gaffney, is working with the global network of science and technology centres to organise debates on all continents around the time of the Planet Under Pressure 2012 open science conference in London, March 2012. The debates will engage the public in discussions about the Earth system and global sustainability with a particular focus on the United Nations Rio+20 Summit, in June 2012. More information: owen.gaffney@igbp.kva.se

IGBP DIARY

2011

July

29-30. PAGES Scientific Steering Committee meeting. Bern, Switzerland.

September

5-10. Land-Ocean-Atmosphere Interactions in the Changing World, an IGBP-sponsored international young scientists' conference, Kaliningrad Oblast, Russia.

8-10. LOICZ Scientific Steering Committee meeting. Yantai, China.

12-15. LOICZ Open Science Conference. Yantai, China.

18-23. iLEAPS Open Science Conference. Garmisch-Partenkirchen, Germany.

27-30. 30th ICSU General Assembly. Rome, Italy.

October

10-13. IGBP Officers Meeting and IGBP workshop, Manaus, Brazil.

24-28. WCRP Open Science Conference - Climate Research in Service to Society. Denver, Colorado, USA.

2012

March

26-29. Planet Under Pressure: New knowledge towards solutions, London, UK.

May

7-10. SOLAS Open Science Conference. Washington State, USA.

10-12. IMBER Scientific Steering Committee meeting. Location to be decided.

September

17-21. IGAC Open Science Conference. Beijing, China.

24-27. SCOR-IGBP-IOC Third Symoposium on the Ocean in a High CO_2 World. Monterey, California, USA.

New IGBP website

IGBP has updated and relaunched its website. The site now contains more information on global change, the Anthropocene and the Great Acceleration. It will run more news, more features and more multimedia content. It links directly to IGBP's Facebook page. Use the new site to download presentations, link to other networks and keep up to date with the latest global-change news. www.igbp.net

Nine policy briefs announced for Rio+20

THE global-change programmes and ICSU are producing nine policy briefs to provide scientific input and leadership to the United Nations Rio+20 Summit, June 2012. The topics for the briefs and white papers are: green economy, international governance, water security, energy security, food security, health, well-being, ecosystem services and biodiversity, interconnected challenges.

The policy briefs will be published in September 2011 to coincide with UN regional preparatory meetings for Rio+20.

The more detailed white papers will be published early 2012, and available at the Planet Under Pressure conference. More information: owen.gaffney@igbp.kva.se

Bringing planetary stewardship to Rio+20

TWENTY years after the iconic 1992 United Nations Earth Summit, the UN will hold the Rio+20 Summit in June 2012.

The UN is preparing for the Summit through a series of preparatory meetings in 2010 and 2011. IGBP and the global-change programmes organised a side event, moderated by *New York Times* writer Andrew Revkin, at the second preparatory meeting held in New York in March 2011.

IGBP Executive Director Sybil Seitzinger discussed planetary and societal risks and the urgent need for planetary stewardship with a packed room of delegates.

Seitzinger's talk was followed by Deborah Rogers from the International Human Dimensions Programme on Global Environmental Change, who discussed the links between equality and sustainability.

The International Council for Science's Senior Policy Advisor, Gisbert Glaser, spoke about the need to improve links between science and international policy.

AN EYE ON THE ARCTIC COAST

© iStockphoto.com/Dan Kite

A recent report entitled *State of the Arctic Coast 2010: Scientific Review and Outlook* provides a comprehensive picture of the status and current and anticipated changes in the most sensitive Arctic coastal areas. The assessment leading up to the report was initiated after a 2007 workshop organised by the LOICZ project in conjunction with the International Permafrost Organisation (IPA) and the International Arctic Science Committee (IASC).

The assessment takes a socio-ecological approach that explores the implications of change for the interaction of humans with nature. The report is a first step towards a continuously updated coastal assessment and aims to identify key issues for scientific enquiry in an international Earth-system research agenda. The document was prepared by an international writing team, including 15 lead authors and 27 contributing authors.

The report is organised in three parts: the first provides an assessment of the state of Arctic coastal systems under three broad disciplinary themes – physical systems, ecological systems and human dimensions; the second examines progress in integrative approaches to monitoring, understanding and managing change in Arctic coastal systems; the third identifies data gaps and research priorities over the coming decade.

State of the Arctic Coast 2010 – Scientific Review and Outlook. Edited by Forbes D L (2011). 178 pp. http://arcticcoasts.org

Global sustainability initiative dominates IGBP scientific committee meeting

THE International Council for Science's new vision for Earth-system research was the focus of IGBP's 26th meeting of its scientific committee, Washington DC, March 2011.

The visioning process for a new ten-year initiative, Earth-system research for global sustainability, culminated in February with an agreement of the five grand challenges. ICSU says: "The initiative will be a joint integrated research strategy that is expected to unify most of the existing global-environmental-change research structures (including DIVERSITAS, IGBP, IHDP, ESSP and possibly some components of WCRP), and fully engage START."

ICSU is creating a "transition team" to build the new international framework for the initiative. Details of the new initiative will be announced at the Planet Under Pressure conference and the Rio+20 Summit, both in 2012.

The IGBP scientific committee meeting was followed by a one-day symposium jointly sponsored by NASA, Global Change: Mounting Pressure on the Earth System.

More information on the ICSU Earth-system vision: www.icsu-visioning.org

New review addresses global bioenergy potential

Recent work assessing the world's capacity to produce bioenergy has led to widely varying estimates. Whereas some studies calculate this capacity to be equivalent to current bioenergy use, others come up with a capacity almost 20 times higher. A new review finds the global bioenergy potential for the middle of this century to be at the lower end of previous estimates, around 200 exajoules (EJ) or more than thrice the current use.

The review, led by Helmut Haberl of the Global Land Project, considered a range of factors for estimating bioenergy potential for the year 2050. These include the area available for bioenergy crops and their expected yields, but also the potential for organic residues to contribute to the generation of bioenergy. The results suggest that over half of the future bioenergy could come from material that is currently underutilised, such as crop residues, animal and municipal waste, and forestry residues.

Uncertainties remain, among other things, regarding the amount and quality of land that could be used to grow crops for bioenergy, the effects of future climate change and the trajectory that future diets would follow.

Haberl H *et al.* (2011) *Current Opinion in Environmental Sustainability* 2: 392-403.

FOREST AND GRASSLAND RESPONSE TO EUROPEAN HEAT WAVES

Europe experienced major heat waves in 2003 and 2006, and such waves are expected to become more frequent in the future. Depletion of soil moisture played a part, but how did the type and distribution of vegetation influence the temperature extremes? A team of researchers associated with IGBP's iLEAPS project reports that forests and grasslands responded in fundamentally different ways during the course of these prolonged heat waves.

The team analysed measurements provided by a network of observation towers in Europe to understand the evolution of surface heating over forests and grasslands. The analyses show that the surface over grasslands is cooler than that over forests during the early stages of a heat wave. This is because of higher evaporation over grass. But eventually this causes soil-moisture depletion in the grasslands, and there is a shift in behaviour as the heat wave advances: the surface over grasslands begins heating up and might cause a shift in the regional climate to even higher temperatures.

Prolonged dry and warm conditions during the summer of 2003 in Europe meant that grassland became the main source of heating during the later stages of the heat wave. This likely explains the extreme temperatures measured in this region in August 2003.

The researchers contend that forests could serve to ameliorate the effects of prolonged and severe heat waves, and also contribute to preserving water by virtue of generally lower evapotranspiration.

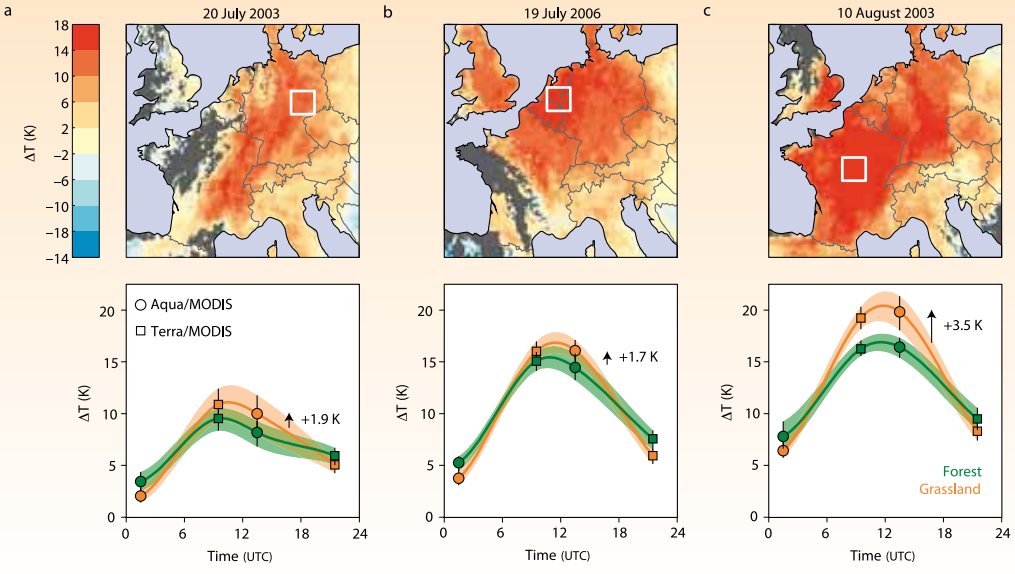


Figure 3 from Teuling A J *et al.*, *Nature Geoscience* 3: 722-727 (2010). Reprinted with permission from Macmillan Publishers Ltd.

EVENTS

2011

July

20-27. 18th INQUA Congress. Bern, Switzerland.

August

14-19. Goldschmidt 2011. Prague, Czech Republic.

September

26-30. World Conference on Marine Biodiversity. Aberdeen, Scotland, UK.

October

24-26. Ocean deoxygenation and implications for marine biogeochemical cycles and ecosystems. Toulouse, France.

November

2-4. Sixth International Symposium on Non-CO_2 Greenhouse Gases (NCGG-6): Science, Policy and Integration. Amsterdam, the Netherlands.

29 November - 2 December. ESA-SOLAS-EGU Conference on Earth Observation for Ocean-Atmosphere Interactions Science. Frascati, Italy.

December

5-9. AGU Fall Meeting. San Francisco, USA.

2012

February

19-24. Ocean Sciences Meeting 2012. Salt Lake City, USA.

April

22-27. European Geosciences Union (EGU) General Assembly. Vienna, Austria.

May

14-18. ICES-PICES Effects of Climate Change on World's Oceans. Yeosu, Korea.

June

4-6. The United Nations Conference on Sustainable Development. Rio de Janeiro, Brazil.

© Stock.xchng - Yenhoon

ECONOMIC IMPACT OF OCEAN ACIDIFICATION

A recent workshop in Monaco was the first of its kind to analyse the economics of ocean acidification. IGBP Deputy Director Wendy Broadgate attended the three-day workshop: "Research on the economics of this issue is still in its infancy. We know ocean acidification will have economic impacts, but have little handle on the true costs – we need research in this area."

The workshop highlighted why natural and social scientists need to work together to assess the costs. The report says: "We need economists to advise biologists and biogeochemists on the exact data required for economic assessments." The objective is to reduce uncertainties biologically and economically.

The report states that some regions are more vulnerable than others. The research community must "identify and prioritise these regions and countries", and alert these nations to the risks.

More information:
Nathalie Hilmi: hilmi@centrescientifique.mc
James Orr: james.orr@isce.ipsl.fr.

Planet Under Pressure attracts over 350 session proposals

The global-change programmes received over 350 session proposals for the Planet Under Pressure conference. Proposals came in from scientists across the globe and from organisations such at the World Trade Organization, the World Health Organization, the United Nations Environment Programme, NASA, European Space Agency and the British Antarctic Survey. The conference will have around 100 sessions. More information: www.planetunderpressure2012.net

James Syvitski to chair IGBP beginning January 2012

Professor James P M Syvitski was appointed recently as the new chairperson of IGBP. He will assume his responsibilities on 1 January 2012, and will succeed Professor Carlos Nobre. The IGBP Chair leads the Scientific Committee, IGBP's main decision-making body.

The US academic is Executive Director of the Community Surface Dynamics Modeling System and brings extensive experience directing large national and international research institutes and programmes. Syvitski specialises in research on rivers, deltas, polar environments, sediment transport and continental margins.

"This is an important time to join IGBP," says Professor Syvitski who is based at the University of Colorado, Boulder. "The defining research question of our age is how do we manage the Earth system – the planet's physical, chemical, biological and social components – responsibly, whilst feeding, clothing and protecting a population predicted to grow to nine billion people? IGBP and its partners are at the centre of this research," he adds.

Mark Stafford Smith addresses Global Sustainability meeting

Planet Under Pressure Co-chair Mark Stafford Smith spoke at a key meeting of Ban Ki-moon's Global Sustainability Panel in April in Madrid, Spain. The high-level panel has been set up to find new solutions to the many interconnected international challenges: climate change, sustainable development, poverty alleviation and others. The panel report, due for publication in January 2012, will feed into the United Nations Rio+20 Summit.

Stafford Smith, former IGBP Vice Chair, discussed ideas for a new paradigm for global sustainability and the need to inject urgency into the international process.

The concept of planetary boundaries was discussed at length, but policymakers expressed concern about equity issues. Dr Stafford Smith says, "It is being interpreted by developing nations as setting another set of thresholds, like two degrees for greenhouse-gas emissions, which the North has already transgressed and the South is now going to be prevented from doing as part of their development." The panel argues the equity issue needs to be addressed for the boundaries idea to gain momentum in international processes.

The panel's report will likely form the foundation for the follow on to the Millennium Development Goals, due to end in 2015. These goals could become the "Sustainable Development Goals". Several members of the Secretary General's panel are invited to participate in the Planet Under Pressure conference.

Did rain bring down the ROMAN EMPIRE?

Analysis of the most complete tree-ring database for Central Europe provides a record of climate change over the past 2500 years. It also reveals synchronies with important historical events, reports **Naomi Lubick**.

In 1789, English historian Edward Gibbon published the final volume of his life's work, *The History of the Decline and Fall of the Roman Empire*. The opus became an instant classic, setting new standards in objectivity for historians. In six volumes, Gibbon painstakingly charted the Empire's final demise, using original reference material where possible. Gibbon blamed the fall on several factors: a loss of civic virtue, the use of barbarians as mercenaries rather than Roman soldiers, and the rise of Christianity, which led to increased pacifism and widespread beliefs that a better life awaited Roman citizens after death.

Unprecedented tree-ring data now provide historians with a new set of original reference materials to add to the arguments over what exactly led to the Roman Empire's demise. Their findings may have led Gibbon to different conclusions.

Each piece of wood also added information to the economic and historical context of the time.

Unravelling the rings

Tree-ring data provide a summer-season climate record with the kind of yearly accuracy that could be useful for historical studies. Dendrochronologists in Europe have been diligently collecting data on oak and pine for decades, in an attempt to fill in the annual temperature and climate records.

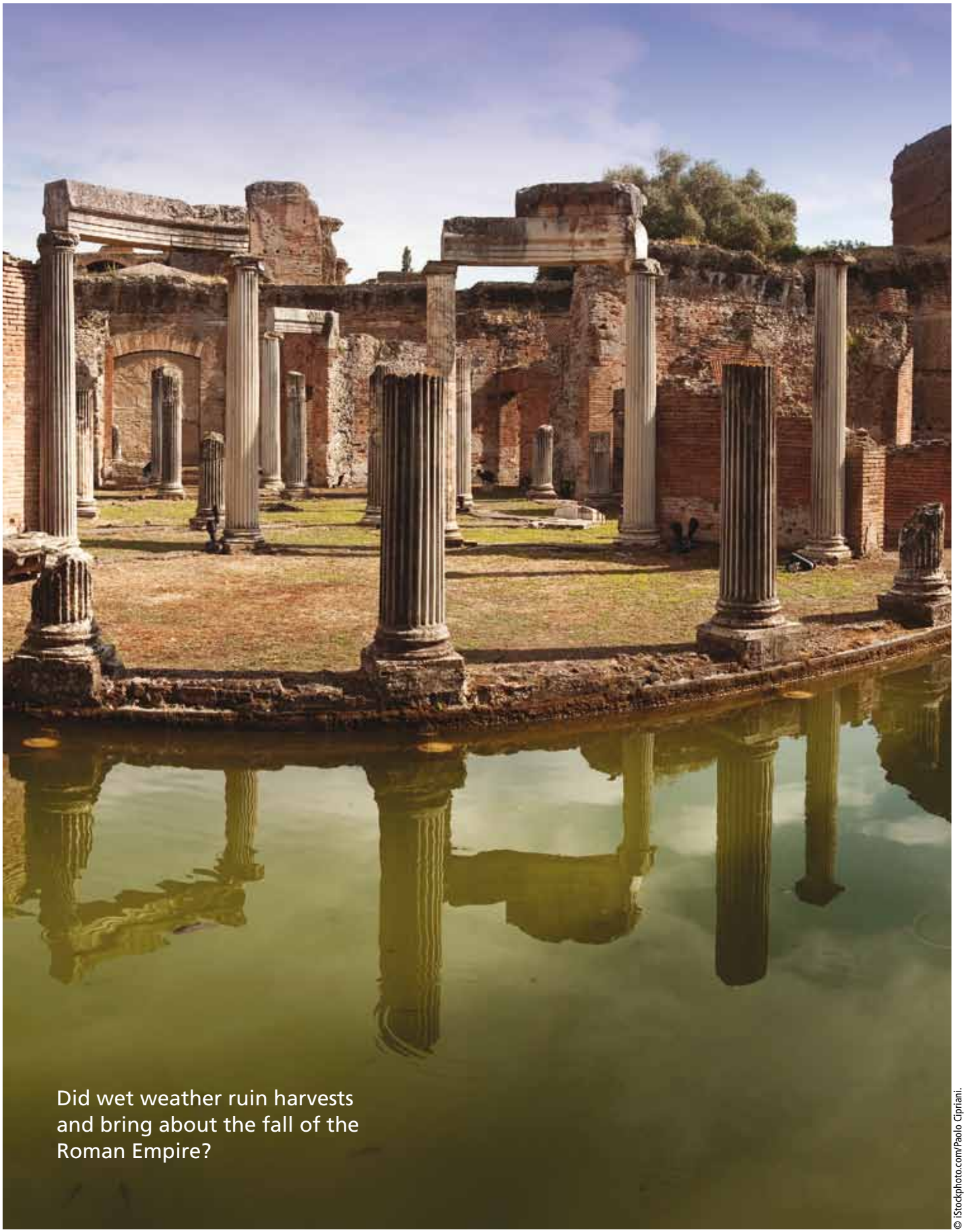
Thick rings imply good years, with warmth and sufficient water to keep a tree growing comfortably in the summer season. Thin rings might indicate meagre water and cooler conditions. But the growth of individual trees is influenced by local climatic conditions. Different conditions within a forest or field might allow one tree at the water's edge to have a great summer, while another – only some distance away – suffers from what looks like mild drought conditions. Tree-ring data thus need to be interpreted carefully before reaching conclusions about regional climate.

The newest and most complete dataset of temperature and precipitation records for Central Europe based on tree rings and extending back 2500 years (Büntgen *et al*. 2011) has now allowed a multidisciplinary team of researchers to carefully reconstruct the climate of the times – and to cautiously link historic events to temperature and precipitation variability.

The research that created this database rests on both scientific and historic data. Led by Ulf Büntgen, a geographer and tree-ring climate specialist at the Swiss Federal Research Institute for Forest, Snow and Landscape (WSL), the research team started with existing tree-ring data that roughly cover the entire Holocene (the past 10,000 years or so). To this the team added samples of wood taken from, for example, stumps drowned in mountain lakes or logs buried in sediments.

The team first compared modern tree-ring data with instrumental climate records to quantify the relationship between tree-ring growth and climate (precipitation and temperature). They used this relationship to glean climate information from the ancient tree rings for which no instrumental records were available. To avoid getting strong local signals from one or a handful of trees in a particular forest or mountain site, the team used data for thousands of pieces of oak wood across Central Europe. Precipitation was reconstructed by using over 7000 oak trees across France and Germany. And 1500 or so stone pine trees from the Austrian Alps region provided information about temperature.

The database included wood samples from historic buildings, where human records told the researchers when the structure was built or the origins of the wood purchased. Found in church beams or in pieces down a well, each piece of wood also added information to the economic and



Did wet weather ruin harvests and bring about the fall of the Roman Empire?

historical context of the time. In good times, people cleared more land and felled more trees in Central Europe, including regions of France, Germany, Switzerland and Austria, the researchers concluded (Figure 1 A). During periods from which fewer wood samples survived, they surmise periods of trouble or poverty.

Other kinds of historic records proved useful for verification: "We have Roman protocols showing repairs of streets," for example, in Switzerland, says co-author Heinz Wanner of the Oeschger Centre for Climate Change Research in Bern, who was co-chair of IGBP's PAGES project. Fewer repairs provide evidence of very little flooding, matching periods of low precipitation.

"The [new] dendroclimatological database is extensive compared with other climate reconstructions," says Eduardo Zorita, a specialist in climate of the past millennia at the Institute for Coastal Research (Helmholtz-Zentrum Geesthacht in Germany). He acknowledges the care the team took in collecting signals from old wood – from semi-fossilised trees to construction beams – and the validation processes they used, for example comparing the data to 20th-century observations of modern tree-ring growth.

The tale in the trees

When all the data are pooled together, some interesting trends emerge (Figure 1 B). From the beginning of the Roman Empire to its peak (c. 50 BC to AD 250), the climate was relatively stable, with warm and wet summers. During the two-and-half centuries or so that followed, though, Europe had "the most unfavourable conditions for agriculture that you can imagine", says Fredrik Charpentier Ljungqvist, a history graduate student at Stockholm University. This interval corresponds to what is known as the Migration Period – a 250-year-period of turmoil and waves of migration.

Reduced climate variability in Europe from AD 1000 to 1200 was coincident with prosperity.

Wet weather that can ruin harvests marked the end of the Roman Empire in the fifth century, and then transitioned to an extremely dry and cold period around AD 550. Better conditions returned again around AD 700, and the reduced climate variability from AD 1000 to 1200 was coincident with prosperity and a growing population. The onset of the Little Ice Age around AD 1300 – marked by higher precipitation and a dip in temperature – seems to coincide with the Great Famine and the Black Death plague pandemic.

The coincidence between changes in climate and important historical events begs the question: how much can climate influence history? Jonathan Overpeck of the University of Arizona is fascinated by the team's conclusions about the links between climate and past societies. The researchers "have managed to put together an amazing picture of human-environment interactions over a couple of thousand years [that is] more comprehensive and convincing than any other job that's been done [before]. I'm pretty amazed at how well their connections make some sense."

Carole Crumley, an anthropologist at the University of North Carolina at Chapel Hill and the Stockholm Resilience Centre, agrees, "I think they are trying to do something that's been missing from most scholarly work in history and archaeology for a very long time. It's rather bizarre that there is a disconnect

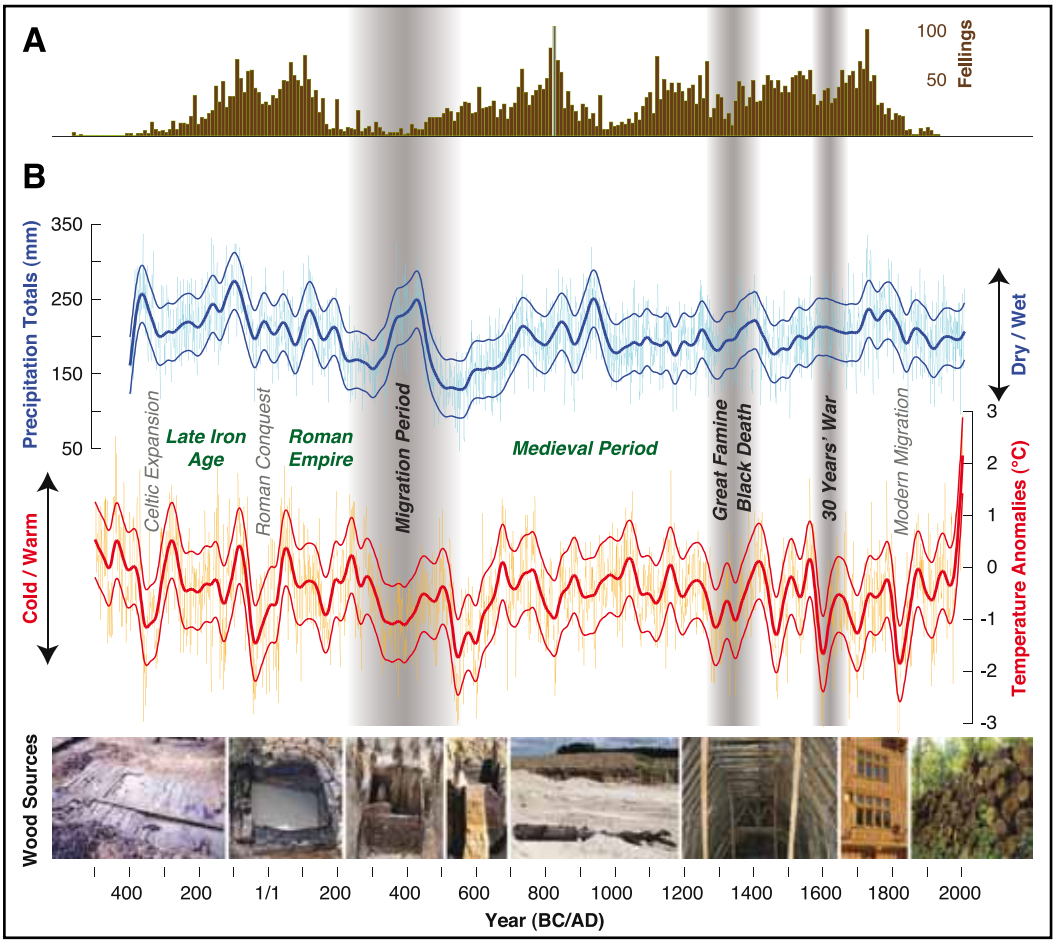


Figure 1. Deciphering the rings. A) Tree felling over the past 2500 years. B) Reconstructed precipitation (April-June) and temperature (June-August) of the last 2500 years. The grey vertical bars indicate key events in European history. Modified after figures 2 and 4 from Büntgen *et al.* (2011) 2500 Years of European Climate Variability and Human Susceptibility. *Science* 331: 578-582. Reprinted with permission from AAAS.

between how humans behave in their surroundings and how that gets communicated in historical documents."

Crumley and colleagues at the Resilience Centre are working to determine different societies' "coping mechanisms" in the face of variability and shifts in climate. For the Romans, for example, being wedded to wheat may have been a problem: over-reliance on a grain that is susceptible to cold and wet weather – prevalent conditions at the end of the empire, according to the new tree-ring data and climate reconstruction. This could have led to shortages of a key commodity. Wheat may well have been the perfect crop during the first three centuries or so of the empire, when it was generally warmer and not as wet according to the database. But during those cold, wet times, history shows multiple revolts because of food shortages. And perhaps people at that time could not shift gears to adjust quickly enough.

"If the Romans had been using rye, they wouldn't have gotten into all that trouble," Crumley comments. On the other hand, she continues, "they may have gotten into trouble in any event," owing to other drivers, such as politics or the "far-flung" nature of the vast empire they were attempting to govern in a uniform fashion. "Some would argue that they were overstretched," she says.

Zorita and others are intrigued by evidence for the rate of deforestation and tree felling, which hints at economic and social conditions. But Zorita cautions against overinterpreting the correlations with historic events. While "human populations had a stronger influence … to shape the landscape and immediate environment earlier than previously thought," Zorita says, "the influence of climate change and variability on the fate of past societies, for instance the Roman Empire, but also in more recent times … is debatable, although certainly worth considering in view of the results presented in the paper." More work is necessary to ensure that the confluence of climate and human events is not just coincidence, he says.

Co-author Wanner also remains personally very cautious when it comes to interpreting human activities with regard to climate change. Specifically, tree-ring data represent summers only, and the need to use models to fill in the winter blanks, so to speak, can lead to uncertainties. More broadly, he says, "it would be too easy to tell the story that climate was driving human development," but correlation does not mean causation. "I think [climate] was one of many different factors."

Büntgen points out that the research team brought together historians, climate modellers, archaeologists and geographers, all of whom "don't necessarily speak the same language", and who have different experiences with statistically relevant data and lines of evidence. "We are not making a causal link," he explains, in comparing climate records with historical events. Climate instead "is an added element – you cannot ignore climate as a driving component" in human activities, particularly for agrarian societies or those otherwise reliant on weather patterns such as seasonal rains.

Past foretells future?

Büntgen and his colleagues conclude that climate and variability in weather patterns ought to be considered for current-day decision-making, something that Overpeck finds entirely reasonable. The researchers "highlight two things climatically: mean trends and variability", he says. "Too often people think [only] of slow increases in mean temperatures" when they think of climate change, Overpeck says, something that "could in itself cause problems. But it's also the extremes superimposed on that long trend: hotter drier conditions such as in 2003 and 2010 in Europe and Russia." In Russia last year in particular, three- to four-degree shifts in temperatures over the course of one week led to deaths, forest fires, crop losses and other problems. Of course, climate researchers are still trying to dissect whether those extremes are related to anthropogenic warming or are part of natural climate variability.

Ljungqvist comments that applying this kind of climate data has inspired "surprisingly little interest among historians" or others working with ancient cultures, "probably because most of this research is published in natural science journals", rather than history or archaeology journals. However, new ideas and culture are not "the only things that change society". Climate is at least one driver in human history and human adaptations to its variability, he says. But most of today's society is not agrarian-based, he argues. Modern responses will be different than those of the Middle Ages, for example.

Still, in periods of steady change, variability such as a sudden drought or massive storms may be the straw that broke the camel's back, Overpeck says – and not just for ancient societies. Büntgen and his colleagues "are actually playing down that likely future extremes will be harder to deal with than these past ones with gradual climate changes". ▮

If the Romans had been using rye, they wouldn't have gotten into all that trouble.

NAOMI LUBICK is a freelance science writer.

REFERENCES

Büntgen U *et al.* (2011) *Science* 331 (6017): 578-582, doi: 10.1126/science.1197175.

THE GLOBAL FIX ON NITROGEN

The International Nitrogen Initiative brings together a range of stakeholders including scientists, industry and policymakers. **Naomi Lubick** discusses its foundations with **James Galloway**.

Nitrogen is essential to plant growth. But despite being the most abundant element in the atmosphere, plants are unable to use this inert form directly. They rely on microbes for its fixation – conversion into a reactive and usable form. In the early 1900s, it became easy to produce nitrogen-based fertiliser: the Haber-Bosch process revolutionised artificial nitrogen fixation, facilitating the production of millions of tons of nitrogen fertiliser.

The extensive use of such products has worked wonders for agriculture, but it has also caused a proliferation of reactive forms of nitrogen in the environment, causing soil acidification and oxygen depletion of waters. The International Nitrogen Initiative (INI) was set up to optimise the benefits of nitrogen while minimising its harmful side effects.

James Galloway, a biogeochemist and the associate dean for the sciences at the University of Virginia's College and Graduate School of Arts and Sciences, was one of the pioneers of INI along with Jan Willem Erisman, a member of IGBP's Scientific Committee, and many others. INI is currently chaired by Cheryl Palm, a senior research scientist at Columbia University's Earth Institute.

We were able to figure out how to get beyond the science and move into policy.

Tell me about the beginnings of INI.

INI had its beginnings in October 2001, when we had the second international nitrogen conference in Potomac, Maryland, near Washington, DC. At the meeting, Jan Willem Erisman stood up and said that what we needed was an international organisation that would coordinate nitrogen research and investigations into integrated policy around the world. After some initial meetings and discussions with potential sponsors, the Scientific Committee on Problems of the Environment (SCOPE) and IGBP ultimately became the two sponsors of the new initiative. We started regional centres, found people to direct them and started setting up an organisation from the grassroots. It was a very exciting time and is still a very exciting organisation.

What prompted the regional model and how did that work out?

Many aspects of nitrogen are a global phenomenon, but different regions use nitrogen in different ways, leading to different releases to and impacts on the environment. We wanted to make sure that the differences among regions could be captured. Regional components also enabled us to try to make sure that our approaches within regions were similar, so in the end you could put everything together and come up with a truly global story. Another driver for a regional approach is that some areas, notably sub-Saharan Africa, are nitrogen poor: there is simply not enough to provide food for people. Nitrogen issues in those areas are as important as, yet are quite different from, the issues in regions where there is too much nitrogen.

How did INI change the global conversation about nitrogen?

First, it connected people all over the world working on nitrogen issues and gave them a forum to discuss and share information. Through that process, we learned much more about what was happening in East Asia, South Asia, Latin America and Africa. And I suspect that people from those regions learned a lot more from the other regions that they weren't part of.

And by having this organisation, we were able to figure out how to get beyond the science and move into policy. That's been an increasing focus of INI. It's tough because nitrogen is pretty

Cutting down on food waste is one way to decrease our nitrogen footprint.

complicated. The message has to be focused, using language that non-scientists can appreciate and understand.

How did INI start to engage stakeholders outside the scientific community?

The Fertilizer Institute of the US provided support in 2001. And since 2004, the INI has had at the table the International Fertilizer Industry Association (IFA), based in Paris. They were very interested in working with the scientific community, but were also very cautious and said, "we don't want to be perceived as the sole supporters of this organisation. We will help you with financial support, but you have to get the bulk of your support from elsewhere" – which we did.

IFA provided financial support for international meetings. We had the 5th one in India in December, and the 6th one will be in 2013 in Africa. Through IFA, we developed connections to the plant nutrition community; now, the International Plant Nutrition Institute is at the table working with us.

Now, my personal goal is getting the animal products and production industry more involved. Whether you are talking about pork chops, cheese, milk or poultry, there's a large and growing demand globally for these animal products, and there are ways of decreasing nitrogen losses to the environment during their production. We would like to work with that industry very much.

On the policy side, INI has hosted policy workshops. Recently we had a meeting in Edinburgh associated with the European nitrogen assessment meeting, Nitrogen and Global Change: Key Findings, Future Challenges. Stakeholders were invited from various UN and government agencies to sit down in one room and say, well, how can we work together to produce a global nitrogen assessment that's so desperately needed?

My personal goal is getting the animal products and production industry more involved.

You had to find ways to translate the science for people who do not have a research background. Have you met with success?

I think we have. Have we had total success? Well, no, because nitrogen is still an issue. The message that we have to get across is, why nitrogen? And part of that is what's the good news and what's the bad news about nitrogen use by human society? And how can you improve the situation while still providing the resources that people want? We are out to work with stakeholders to maximise the beneficial uses of nitrogen, and minimise the detrimental impacts, which is the mantra of the INI.

What are some of the main problems that you would tackle?

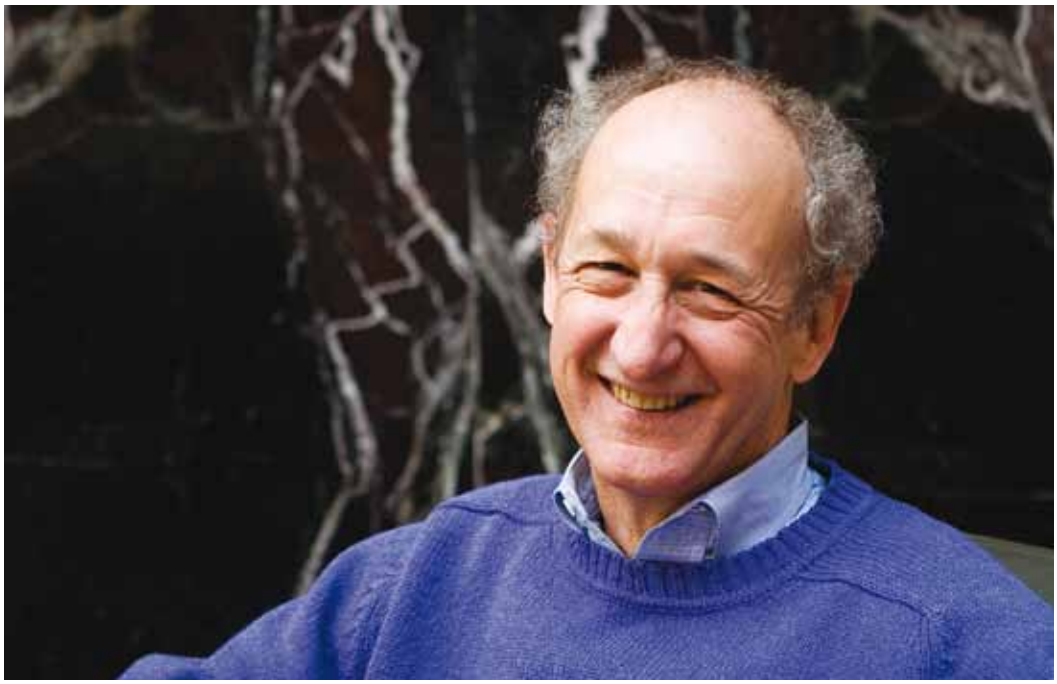
I will break it down into two systems: First, the energy-production system and burning of fossil fuels. Just like carbon dioxide is a waste product [of combustion to make energy], nitrogen oxides are a waste product. They can be captured, they can be controlled. Many countries are doing a good job of that already; it could be better. Other countries are just beginning. But that's like handling any other waste stream: we know the science, we know the engineering, we have the policy instruments. It's a matter of political and social will.

The second major system is food production. We estimate that of all the nitrogen that's used to produce food, only about 15-20 percent actually enters a person's mouth. The rest is lost to the environment during the food-production process.

One of the things that my colleagues and I have developed is the N-Print Project (N-print.org). Featured right on the front page of the website for the INI, you can go in there and enter the amount and types of food you eat, the kind of car you drive, what kind of house you live in, and actually see how much nitrogen is lost to the

Non-identical twins

Carbon dioxide (CO_2) and nitrogen compounds pose twin challenges to society. Both are bi-products of anthropogenic processes: CO_2 of the burning of fossil fuels and nitrogen compounds of food production and the burning of fossil fuels. But Galloway points out an important difference between the two. Whereas there is a degree of choice regarding the extent to which we burn fossil fuels to generate energy – flying is desirable but not essential – we have no alternative but to grow food for a burgeoning population. We could one day burn fewer fossil fuels and switch to other forms of energy. But releasing reactive nitrogen to the environment during food production is unavoidable. For this reason, approaches to dealing with increased CO_2 emissions and the proliferation of reactive nitrogen are different. INI must work to help producers and policymakers minimise nitrogen waste, but the approach cannot be to stop people from using nitrogen altogether.



Jane Haley/University of Virginia, Office of Public Affairs

James Galloway was one of the pioneers of the International Nitrogen Initiative.

environment due to a person's energy and food lifestyle – and then the user can ask questions. What if I decreased my meat consumption? Instead of having it five times a week, what if I had it once a week? Then right on the screen it shows you how your nitrogen footprint diminishes.

What surprises people most when they look at their footprint?

Let me recast your question another way: what are the really obvious things that people could do to decrease their nitrogen footprint? There are two very simple unambiguous things they can do.

One is cutting down on food wastage. In the US, of the food that is purchased in the grocery store or purchased by a restaurant for serving customers, 30-40 percent is wasted. It is not consumed by people. By merely cutting down on food waste, you decrease the amount of nitrogen needed to grow food. That's relatively easy to do because nobody really likes to waste food.

The other is tougher. In the US, the average amount of nitrogen consumed each year by a person is about 5 kilograms of nitrogen per person per year – and that's in the milk we drink, the meat and soybeans we eat, it's the protein we take in, expressed in terms of nitrogen. Animal protein is more nitrogen-intensive in its production as a food commodity than plant protein. The US Department of Agriculture says that on average, an adult only needs 3 kilograms of nitrogen per year. If people in the United States stop overconsuming protein, that would decrease by about a factor of two the amount of nitrogen lost to the environment in the US.

Then you get to the other sources: using fertiliser on lawns, etc. While they have some local impacts, when you are talking about looking at a total system, it's food waste and the type and amount of protein consumed that are the two big ones.

What are points that INI could focus on in the future?

As to scientific research, the INI has a real opportunity to play a role in Asia. There you are going to have an increasing amount of nitrogen lost to the environment due to increasing populations and increased consumption of protein, especially animal products, on a per capita basis and increased consumption of energy on a per capita basis. The INI has a story to tell, and through its East Asian and its South Asian centres, it has a platform to tell that story. And this story should be told not just to scientists working there, but also to a broader audience of stakeholders, including policymakers.

INI has a real opportunity to play a role in Asia.

There is currently an IGBP synthesis on nitrogen and climate that is being led by Jan Willem Erisman to help society better understand the relationships. Nitrogen has both direct and indirect contributions to climate change. The direct contributions are increased emissions of N_2O (nitrous oxide) to the atmosphere. The indirect contributions include increased concentrations of O_3 (ozone). Both N_2O and O_3 are greenhouse gases and contribute to atmospheric warming. Another indirect contribution is the increased loading of nitrogen-containing aerosols, which have the potential to scatter solar radiation and will act as a cooling agent.

On the policy side, the INI is right now an independent organisation associated with SCOPE and IGBP. In my personal view, the more the official connection to recognised international bodies, the more its potential impact. The Food and Agricultural Organization (FAO) is an obvious one because of the food aspects. But the challenge of nitrogen is that it needs to be more than one or two organisations. Because it's not just food, the environment or energy. It's everything. ▮

NAOMI LUBICK is a freelance science writer.

> "…the task we have now to undertake, in attempting to estimate the long-term effects of our actions both on the biosphere and on human societies, is so immense that in relation to it our ignorance is almost total."
>
> John Passmore (1974)

LEARNING FROM THE PAST

When it comes to managing the environment, we rarely look beyond the past few years to inform decisions. **John Dearing** says this needs to change.

We have advanced quite a bit since John Passmore, writing more than 35 years ago, considered our lack of understanding about human impacts on nature. Earth-system science has revolutionised the way we think about the interconnectedness of the world's ecosystems and human activities. Computing power has driven the development of global climate models and produced future scenarios of environmental change that affect global politics and policy. Models can now help assess impacts at the global and regional levels. And new theories and concepts about ecological services, resilience, tipping points and adaptation have emerged.

But Passmore's focus on the *long-term effects* of our actions on the biosphere and on human societies is still valid. In contemporary parlance, we want to assess how socio-ecological systems will respond to the mix of climate and the economic and social stresses likely to be experienced. Only then will we have sufficient information to determine the optimum strategy for managing landscapes and ecosystems for the next decades.

Social and ecological processes operate over different timescales.

Complexity science suggests that we might benefit from treating human activities and ecological systems as evolving systems for which the present is the latest point in a time continuum (Dearing *et al.* 2010). A key element is the idea that social and ecological processes operate over different timescales (Figure 1). For example, major shifts in social structure may reflect changes in culture and technology taking place over centuries. At shorter timescales, accelerated soil erosion observed over a decade might be coupled to the introduction of new agricultural technologies. And at even shorter timescales, fire and flooding may be a direct consequence of seasonal climate. Identifying these individual timescales is important enough, but knowing how these different processes interact with each other at any point in time lies right at the heart of improving predictability. If we can reconstruct, and even model, interactions in the past we increase the chance to anticipate the future with more certainty. It follows that we need to emphasise more the longer, historical changes in many social and ecological processes and not to rely so much on short-term information for a few. This is exemplified by two case studies from Australia.

Links between systems

Mark Stafford Smith and colleagues, in their 2007 study, show how a historical perspective of ecological and social change offers rich insights into the interlinkages between society and ecosystems. The researchers focused on a period from the 1890s to the beginning of this century. During the 20th century, some Australian rangelands repeatedly turned to deserts. The reason was a complex interplay of environmental and social factors including, for example, long-term climate variability (the El Nino-Southern Oscillation variability), grazing, the local and global economies, local environmental knowledge and local decisions.

The study found that

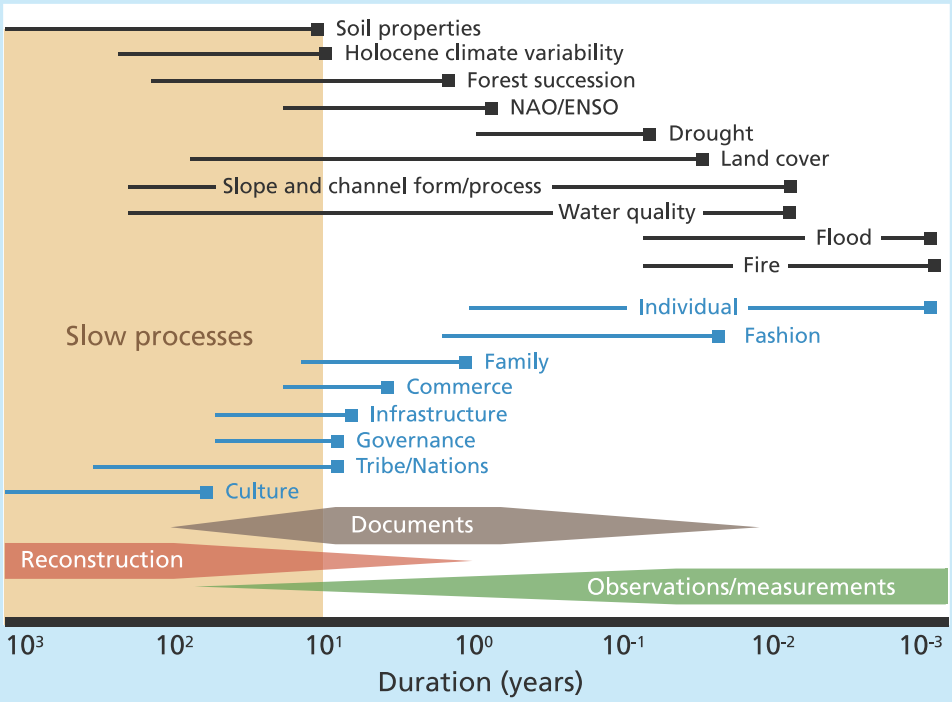


Figure 1. Slow and fast processes. Timescales for a range of biophysical and socioeconomic phenomena range from 'fast' sub-annual events (e.g. floods, fire) to 'slow' multi-decadal and centennial changes (e.g. culture). Understanding contemporary socio-ecological systems may require information from a similar range of timescales, but sources of information become more limited for longer timescales. The sources of information available for each segment of timescale with respect to the present is depicted by the lower horizontal bars. Observations and measurements (for example, instruments, remote sensing, censuses and economic statistics), and documents (for example, diaries, gazetteers and land-use descriptions) may be available for only relatively short timescales. Changes over longer timescales that are essential for assessing the role of 'slow' processes (tan vertical bar) may need to be reconstructed. Reconstruction covers all the palaeoenvironmental fields including archaeology, palaeoecology, palaeoclimatology and palaeohydrology, which interpret artefacts and natural sediment archives (e.g. lake sediments, stalagmites, peat) in terms of past environment and society (Dearing *et al.* 2010).

Saline water body from the Murray Basin.

Peter Gell

Australian farmers apparently responded to declining rainfall and pasture in similar ways throughout the 20th century: in some ways, history repeated itself (Figure 2). A number of self-reinforcing steps seem to have played a part. Hindsight allows us to see that in these event sequences there was invariably a decade or so before the drought when both commodity prices and weather conditions were favourable by chance. This encouraged high livestock numbers and thus heavier grazing, habits that did not change much even after the drought was under way. Grazing pressure led to a loss of pasture quality as each drought developed, and each successive drought accelerated soil degradation.

Communities understood climate variability but on relatively short timescales.

The study found that the communities understood climate variability but on relatively short timescales. Longer-term variability – changes that encompass most of the working lives of individuals – was overlooked. As a result, the expectations of the farmers and communities regarding, for example, the number of livestock that the local environment could support, were based on their experience of environmental conditions during their lifetimes. Managers were most likely to be affected by rare events that they experienced early on in their careers. Similarly, slow patterns of changes in commodity prices were also overlooked. Once a drought had developed, the government offered fodder and subsidies in some events, limiting the incentives farmers had for reducing livestock numbers. This simply heightened the grazing pressure on a declining resource, locking the system in a cycle of degradation.

This historical analysis helps uncover the reasons for changes in a socio-ecological system and provides a sounder basis for designing optimum strategies for sustainable land management. In the case of Australia, the study's authors suggest that while it is important to manage grazing and fires at the local level, it is not sufficient. This is because long-term processes and feedbacks are difficult for individual land managers to take into account based on experience gained during their lives. Alliances between the government, industry and research institutions at the regional levels need to step in. Such alliances can ensure that those charged with decision-making at the local scale have access to knowledge about long-term climate cycles and trends, and receive advance warning of potential environmental or economic disturbances. Stafford Smith and colleagues emphasise that both environmental and socio-economic variability were responsible for the desertification episodes. They suggest that it is important to monitor and understand such variability, and to use this understanding to inform policy.

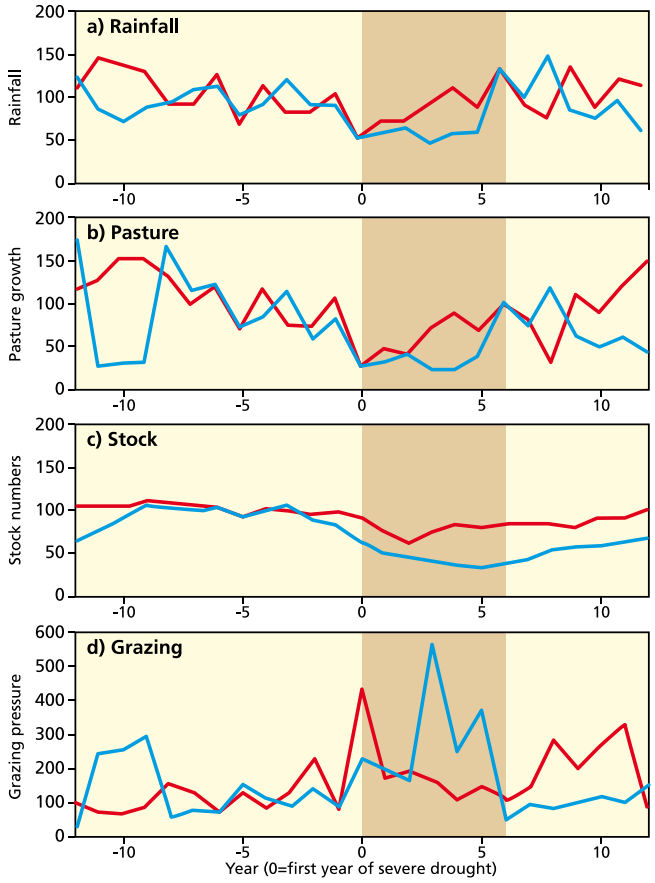


Figure 2. History repeats itself. The history of desertification in Australia since the late 19th century is characterised by a sequence of devastating desertification events. The figure shows normalised curves of a) rainfall, b) simulated pasture growth, c) livestock numbers and d) grazing pressure over more than 20 years that cover the time before, during and following a drought period (brown vertical bar).

Red line: means of relatively short droughts in 1925-29, 1941-44, 1964-67 and 1984-87.

Blue line: means of relatively long droughts in 1898-1902, 1935-40 and 1958-66.

The similarly shaped red and blue curves suggest broadly uniform trajectories for the pastoral socio-ecological system, irrespective of the length of drought or historical period. Farmers responded to declining rainfall and pasture in similar ways, which repeatedly led to unsustainable grazing pressure in the middle years of a drought. They did not heed the lessons from the past. After Stafford Smith *et al.* (2007). Copyright (2007) National Academy of Sciences, USA.

Evolution of socio-ecological systems

As the study discussed above shows, many processes operate over timescales longer than we have direct information for. Instrumental, documentary, palaeo-environmental and archaeological records within regions can thus be helpful in providing "socio-ecological profiles". Such profiles can help in developing policies and strategies in regions where successful management of key environmental processes, ecological services and their interaction is critical (Dearing *et al*. 2010).

Peter Gell and colleagues, in their 2007 study, have done exactly this for the Murray-Darling basin. This basin is possibly Australia's most critical resource management issue, with 95 percent of its river length degraded. The Murray lakes and lagoons are under pressure from different stressors, with the Coorong lagoon system – a coastal wetland of international significance – being a particular concern. In the past, the Coorong used to be an open system and received clear water from the hinterland and the ocean with flows from the Murray River maintaining an active

estuary mouth. In contrast, the modern Coorong is hypersaline, turbid, deficient in oxygen and effectively closed. What happened? To find out, Gell and colleagues integrated decadal reconstructions of water quality (as inferred from a study of diatoms) and land cover (as inferred from pollen analysis) at many sites with land-use histories and hydrological modelling. They were thus able to reconstruct interactions and feedback through space and time.

It turns out that historical land clearance that began two centuries ago triggered a cascade of linked but different biogeochemical changes (Figure 3). Clearance activities, livestock grazing and irrigation caused erosion and groundwater levels to rise, which increased salinity and sodicity levels (the amount of sodium in irrigation water), further increasing erosion. Eroded soils carried native phosphorus to low-lying lakes and coastal lagoons causing increased sedimentation, turbidity and depletion in oxygen levels. More elevated lakes continued to become more saline and eventually acidified.

Naturally the government wants to reverse this trend. It wants to restore the Coorong system by using 1985 as a baseline. Management options include prioritising the Murray's divertible flow to support wetland restoration. There are plans for afforestation in order to combat soil erosion and soil salinity. But these options may result in new problems. A baseline reference from 1985 overlooks the fact that the wetlands have been degraded for almost a century. Restoration efforts may need to be far more rigorous than anticipated if they are to be successful. Diverting river flows at a time when climate change is projected to drive down river flows by as much as 25 percent by 2030 would limit water for other uses, like irrigation. It seems that most development occurred during a flood-dominated regime, yet we may now be in a drought regime. Taking the short-term view seems to have given an unrealistically optimistic view of the available resource. To design more realistic management strategies, it would be beneficial to view the history of the present landscape in terms of an evolving set of interacting processes.

Lessons from the past

The 30-year update on *Limits to Growth* (Meadows *et al*. 2005) considers this problem in terms of how the global society may make the transition to sustainable systems. It rejects an emphasis on maintaining the status quo or finding new technological/economic fixes in favour of "changing the structure of the system". In other words, we need to be doing things differently. To do so, however, we need to be aware of the complexity of the system. Societies and ecosystems can change slowly over long periods of time before crossing thresholds and undergoing sudden changes. The timescales for societal change may be different from those for environmental change, leading to complex interactions and a diversity of states. This means that our ability to say when and where the changes will occur is always likely to be extremely limited, and there are no easy ways to remove the spectre of unpredictability. But a combination of a historical perspective and complexity science may help – especially as we focus more on designing adaptation strategies at regional scales. Managers everywhere should know that their options will be often constrained by the legacy of past decisions affecting the processes they seek to control. In the same vein, they need to be aware of the responsibility they have to future land managers who may operate in a time that lies well beyond their own planning horizon.

We need to be aware of the complexity of the system.

JOHN DEARING is professor of physical geography at the School of Geography, University of Southampton, Southampton SO17 1BJ, UK.
E-mail: j.dearing@soton.ac.uk

MORE INFORMATION:

Leading the interdisciplinary integration of historical information are the PAGES Past Human-Climate-Ecosystem Interactions focus and the Integrated History and Future of People on Earth (IHOPE) project, co-sponsored by IGBP's AIMES and PAGES projects, and IHDP.

Thanks to Peter Gell and Mark Stafford Smith for comments on the text.

REFERENCES

Dearing J A, Braimoh A K, Reenberg A, Turner B L II and van der Leeuw S (2010) *Ecology and Society* 15: 21

Gell P A (2007), in *Fresh Water: New Perspectives on Water in Australia* edited by Potter E, Mackinnon A, McKenzie S, McKay J. Melbourne University Press. Melbourne, Australia. 21-30 pp.

Gell P A, Jones R and MacGregor A (2007) *Past Global Changes (PAGES) News* 15: 13-15.

Meadows D, Randers J and Meadows D (2005) *Limits to Growth: The 30-year Update*. Earthscan, London.

Passmore J (1974) *Man's Responsibility for Nature*. Duckworth, London.

Stafford Smith D M *et al.* (2007) *Proceedings of the National Academy of Sciences of the United States of America* 104: 20690-20695.

IN THE LINE OF FIRE

Scientists who published the famous "hockey stick" graph experienced sustained attacks soon after the figure was incorporated in the 2001 report from the Intergovernmental Panel on Climate Change. Now one of those scientists, **Ray Bradley**, has written a very personal account of his experience. He spoke to **Owen Gaffney** about his new book.

The "hockey stick" refers to a figure documenting the 1000-year temperature record that rises steeply from the end of the 19th century after a centuries-long gradual decline. This figure has been the public face of climate science during the past decade. But almost since the day it was published, the scientists responsible came under attack. Ray Bradley, a member of the IGBP Scientific Committee and one of the architects of the figure, found himself in a highly charged environment. He recounts his experiences in a new book, *Global Warming and Political Intimidation: How Politicians Cracked Down on Scientists as the Earth Heated Up* (University of Massachusetts Press: www.umass.edu/umpress/spr_11/bradley.htm).

This book is really the story of the "hockey stick". How does it begin?

In 1998, a post-doc, Mike Mann, Malcolm Hughes and I published an article in *Nature* on climate in the last 600 years (Mann *et al*. 1998). Then, in 1999, we published another article in *Geophysical Research Letters* on temperature over the last 1000 years (Mann *et al*. 1999). The title was "Northern hemisphere temperatures during the past millennium: inferences, uncertainties, and limitations." We were emphasising the uncertain nature of the problem. But nevertheless, when it got picked up by the summary for policymakers of the third Intergovernmental Panel on Climate Change (IPCC) report, important caveats were left out.

In my opinion, these people wish to limit the IPCC's damage to their interests.

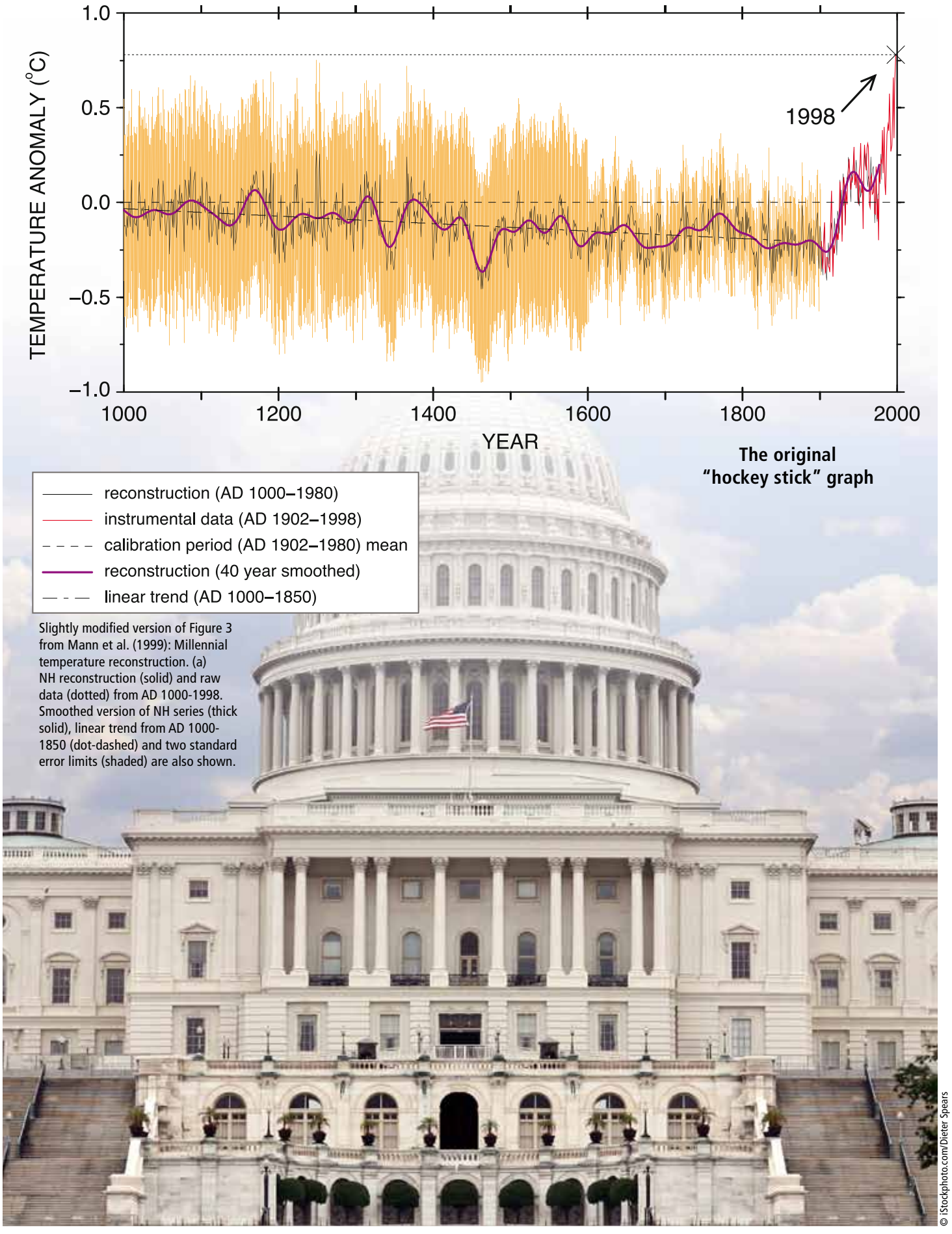
It became almost a symbol of the IPCC. Is that fair?

Yes. It became an icon for global warming because we argued that the decade of the nineties was the warmest for 1000 years. And, because it became a symbol of the IPCC it was a target of attack by those opposed to legislation to control greenhouse gases. In my opinion, these people wish to limit the IPCC's damage to their interests.

Who are we talking about?

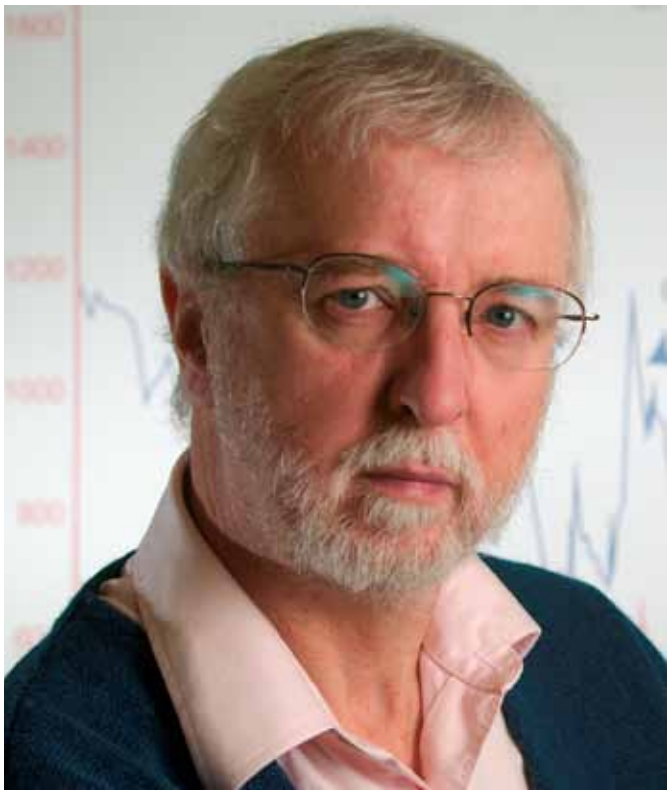
Some wealthy foundations, quasi-political organisations and energy companies oppose legislation to control greenhouse gases. And so, some of their sympathisers in Congress were encouraged to question the veracity of the IPCC. They were determined to sow seeds of doubt about the quality and reliability of climate science and the conclusions that led to the IPCC saying that human activities were causing the climate to change.

But in the IPCC Third Assessment, a report of over 880 pages, the "hockey stick" occupied less than one page. There were more than 200 figures in the book. The "hockey stick" figure was only one of them. It is quite obvious that



The original "hockey stick" graph

Slightly modified version of Figure 3 from Mann et al. (1999): Millennial temperature reconstruction. (a) NH reconstruction (solid) and raw data (dotted) from AD 1000-1998. Smoothed version of NH series (thick solid), linear trend from AD 1000-1850 (dot-dashed) and two standard error limits (shaded) are also shown.



Ray Bradley, a member of IGBP's Scientific Committee, was one of the architects of the "hockey stick" graph.

our graph was not the basis for the IPCC's conclusions. If it had never been included, the physical arguments for human-induced global warming would still have been compelling.

When did the US Congress get involved?

The book starts out with a hearing I went to on Capitol Hill. It was 17 May 2000 and I was there to testify about global warming to the Senate Committee on Commerce, Science and Transportation. The experience was positive. Republican Senator John McCain chaired the committee. John Kerry was the ranking minority member. McCain openly admitted his lack of knowledge of the issue and was asking for help. I felt there was a good reaction to the testimonies.

When did relations begin to deteriorate?

Joe Barton, a Republican Congressman from Texas, became chairman of the important House Energy and Commerce Committee.

In 2005, Barton wrote to me, Mike Mann and Malcolm Hughes and demanded a whole heap of information. This letter was from the Subcommittee on Oversight and Investigations and it was intimidating. You felt like you were about to be indicted. That you'd done wrong.

You felt like you were about to be indicted.

Oddly, they were not asking for information specifically about the "hockey stick" paper, but about our background, how much money we had ever received, and a lot of intrusive information about our careers. And asking for all emails of everyone who had ever written to us asking for information or data, and how we'd responded to those requests.

What was the point of this letter?

In all of these things, they are not attempting to attack the scientists, they are trying to attack the credibility of the IPCC. If you happen to be one of the people who get in the way, they do not care. They are not interested in whether they destroy your career or your reputation. Their simple goal is to sow uncertainty in the minds of the public. They have been very successful at this in the US. They have managed to make people think climate scientists are a bunch of fakes and manipulators of data, and people who hide data. None of which is true.

Do you think the media are in collusion with these people?

I don't think they are in collusion but I think they are being extremely naïve in how they are being manipulated, or maybe they are only interested in marketing their business interests – selling papers – so any controversy is grist to the mill.

Another US Senator, James Inhofe, is also a prominent critic.

Inhofe says global warming is the greatest hoax ever perpetrated on the American people. He has teams of people attempting to deconstruct the IPCC. He issues his own version of the IPCC report and tries to destroy everything within the IPCC reports.

Inhofe is from Oklahoma. You will notice that Texas and Oklahoma play prominent roles in this story because they are the oil states.

Barton also commissioned a report on the veracity of the "hockey stick". What was your response to that?

Barton was not content with a National Academy of Sciences report that did not endorse his opinions, so he commissioned a team of statisticians to evaluate our methods. He wanted all our supposedly egregious errors exposed and made part of the congressional record.

The report criticised the statistical procedures we used, arguing that "hockey stick"-shaped records will always result from the methods we used. But this is not the case, if you follow our procedures in full. This has been shown by many other climate scientists in later studies.

Besides, we have since shown that even if you entirely avoid the procedure Barton's statisticians objected to, and simply average all the data we used, you get the same "hockey stick" result. Simply put, the "hockey stick" is bomb-proof. No amount of data manipulation will make it go away.

As I read their report, I must say I was impressed by how well the statisticians had grasped the intricacies of palaeoclimatology and, in particular, high-resolution studies of tree rings, ice cores and corals. Their section on the problems of using tree

rings, and of the important points that one must take into account, struck me as strangely familiar. It was only later that I realised that large sections of the report had been lifted verbatim from my own 1999 book on the subject. I don't think the word "irony" does justice to the fact that somebody commissioned by Congress to investigate the wrongdoings my colleagues and I had supposedly committed had the nerve to reproduce entire paragraphs from a book written by one of the people under investigation without citing the source.

In March 2010, Inhofe called for a criminal investigation of 17 climate scientists. You were one of the 17. How did you feel when you heard that news?

Inhofe knew that his report criticising the IPCC would sink like a stone, as the media was losing interest. So he coupled it with a statement that 17 scientists should be investigated by the department of justice for these various "offences", and of course that hit the headlines. By that time Obama was in the White House so I could shrug it off.

If Bush had been in the White House, it would have been a different story.

Have things changed under Obama?

Obama once talked about climate change but now he cannot because the political climate in Washington has put the topic "off-limits". He talks about "green jobs". That is the best he can do.

Climate is the litmus test for new Republicans joining the party. It is like abortion. Anybody who supports the notion that there is anthropogenic climate change and that there should be controls on greenhouse gases will never receive the support of the right wing of the Republican Party.

Even John McCain, who was initially persuaded that global warming is an important problem, has now dropped it. He never even talks about it anymore.

The treatment of scientists in the US has been described by some sections of the media as akin to McCarthy's witch-hunts in the 1950s. Is this fair?

It is McCarthyism. They are trying to tar scientists with this notion that they are frauds. That scientists are manipulating data. That researchers have a hidden agenda: to cripple the free market.

This is what the book is about. Politicians are using the power of the state to intimidate individuals with no power. They have the resources. They can indict you. They can subpoena you. And you have to defend yourself at your own expense. Even if their charges are completely false they can still bankrupt you.

George Soros called these right-wing reactionaries "market fundamentalists". These people believe there should be no regulation. The market will solve environmental problems, if there are any. But history shows that there is very little evidence to support that view.

Europe has largely avoided the extreme political polarisation of climate science. Can the US learn any lessons from the UK or Germany?

Unfortunately, I think the change is going in the opposite direction. Private organisations are being set up in Australia and Europe to proselytise the same story. They want to internationalise the whole issue. Far from the US learning from Europe. I think it is going to go in the other direction.

How has all of this pressure affected careers and reputations?

I think within our field it has not had much of an impact. But to the general public the impact is massive. People are confused and sceptical about climate science. The strategy adopted by the energy industry, the free-market fundamentalists and their Republican allies has been very effective. We have been impotent: we don't have the resources.

You finish the book discussing a civil investigative demand to Mike Mann's former employer, the University of Virginia, from the Attorney General of Virginia, Ken Cuccinelli. This demand was described in *Nature* as an "ideologically motivated inquisition". How did the university respond?

Thomas Jefferson established the University of Virginia in 1819. In its eloquent defence to Cuccinelli, the university quotes Jefferson's founding statement: "scientific enquiry should be free from political intimidation." The university rejected Cuccinelli's demand, and the court sided with the university.

Unfortunately, Cuccinelli has not given up, and he has refiled his demand in court. This demonstrates the point of my book: that public officials are using their positions to pursue a politically motivated agenda, to intimidate scientists and to try to denigrate or suppress research that does not support their position. ▮

OWEN GAFFNEY is Director of Communications at IGBP.

Far from the US learning from Europe, I think it is going to go in the other direction.

REFERENCES

Mann M E, Bradley R S and Hughes M K (1998) *Nature* 392: 779-787, doi:10.1038/33859.

Mann M E, Bradley R S and Hughes M K (1999) *Geophysical Research Letters* 26: 759-762, doi:10.1029/1999GL900070.

Tracking groundwater depletion

As water demand rises rapidly, some regions are withdrawing groundwater faster than it can recharge. Now scientists can couple new space-based observations with models and data to quantify global and regional groundwater changes, reports **Ninad Bondre.**

While conducting fieldwork in the villages of western India, my colleagues and I were often trailed by a group of curious onlookers. When we informed them that we were geologists, observing rocks and collecting samples, someone invariably asked: "Could you give me some tips about water?" It was groundwater that they were interested in, wanting to know the best locations to dig productive wells or how long they would continue to get an assured supply from their existing wells. It is no surprise that for these subsistence farmers and small landholders at the mercy of the Southwest Monsoon, a prognosis about local groundwater was critical.

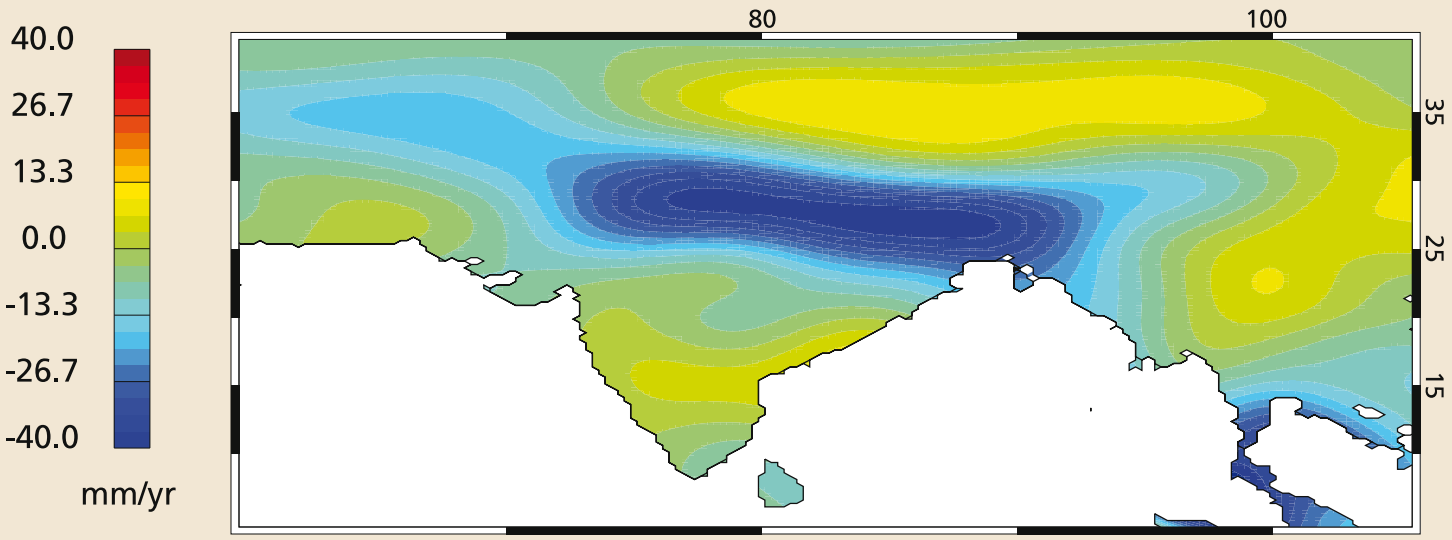
Globally, groundwater is about a quarter of the total water consumed (Döll 2009). Irrigated agriculture accounts for almost 80 percent of freshwater use, and in India, almost half of the water used for irrigation comes from aquifers. Groundwater can be relied upon during times of low surface-water availability, particularly in regions dominated by strongly seasonal precipitation. And it is an assured source of relatively clean water in regions where surface water sources are highly polluted (Döll 2009). But increases in population, industrialisation and the areas of land brought under irrigation are putting unprecedented pressure on groundwater resources.

Natural recharge is no longer replenishing the aquifers adequately.

A case in point is the northern Indian subcontinent. We knew from well data that groundwater withdrawals here were exceeding recharge, leading to a lowering of water tables. But the scale and seriousness of the problem became apparent in 2009, after two independent groups published their findings. Using observations made by NASA's Gravity Recovery and Climate Experiment (GRACE) satellites, these studies showed a dramatic depletion of groundwater in this region from 2002-2008 (Rodell *et al*. 2009; Tiwari *et al*. 2009). Consistently high rates of withdrawal lowered water tables by up to 4 cm/year (see figure). Natural recharge is no longer replenishing the aquifers adequately.

GRACE data have also provided insights into the scale of groundwater withdrawal in other regions. In California's agriculturally productive Central Valley, for example, the water tables have been lowering at the rate of 2 cm/year during the past six years or so (Famiglietti *et al.* 2011). Interestingly, the GRACE mission – a pair of satellites in polar orbit constantly measuring the distance between each other – had nothing to do with monitoring groundwater. It was designed to measure changes in the Earth's gravitational field, which could then be used to infer regional variations in mass. But as Felicity Barringer writes in the *New York Times* (30 May), the creative use of GRACE by hydrologists has provided a powerful new way to monitor regional and global changes in groundwater, which until recently relied heavily on compilation of data gathered from thousands of individual wells.

The concerns raised by GRACE-based studies are confirmed by other approaches. A global analysis published last year used a hydrological model to quantify recharge and a variety of records to estimate withdrawal (Wada *et*



Changes in groundwater storage in the Indian subcontinent (mm/year) estimated using GRACE data. Note the zone of marked depletion extending from the northwest to the northeast. Figure courtesy Sean Swenson, University Corporation for Atmospheric Research.

al. 2010). The results show that globally, the difference between withdrawal and recharge has more than doubled compared to what it was in 1960.

This is not to say that groundwater is depleting uniformly around the world. Recharge is sufficient to balance withdrawal in many regions, for example in the northeastern United States and much of Europe. But what is worrying about recent results is that groundwater use is unsustainable in precisely those regions that will continue to rely on it the most for irrigation and domestic consumption – highly populated regions like northern India and arid or semi-arid regions like the southwestern United States.

Climate change adds a new twist to the tale. There is some potentially good news for regions like northern India in that models indicate no substantial change in groundwater recharge by 2050, and even a slight increase (Döll 2009). This is because of an expected increase in precipitation in this region as the Earth warms (although the projections of different models regarding precipitation vary widely). But Tiwari *et al.* (2010) point out that a warmer world will entail greater evapotranspiration, which might balance out the gains in this region due to increased precipitation and recharge. And future demand for groundwater in the region could be different from current demand.

Studies that rely on GRACE data and global hydrological models provide a broad overview of groundwater depletion. This is also the case with simulations of changes in groundwater recharge due to future climate change. Such studies could be invaluable in informing policy decisions at the state or national level. However, they cannot be relied on solely by those entrusted with managing smaller administrative units.

The challenge is to distil the relevance of global findings to local settings – such as those farmers in western India – accounting for a host of variables including changes in population, socio-economic conditions, demand and future availability of surface water. We need to act now to find solutions to ensure that these underground stores of water remain wellsprings for the future.

Climate change adds a new twist to the tale.

NINAD BONDRE is Science Editor at IGBP.

REFERENCES

Barringer F (2011) *The New York Times*, 30 May. http://www.nytimes.com/2011/05/31/science/31water.html?pagewanted=1&_r=1&emc=eta1

Famiglietti J *et al.* (2011) *Geophysical Research Letters* 38: L03403, doi: 10.1029/2010GL046442.

Döll P (2009) *Environmental Research Letters* 4: 035006, doi:10.1088/1748-9326/4/3/035006.

Rodell M, Velicogna I and Famiglietti J S (2009) *Nature* 460: 999-1002, doi:10.1038/nature08238.

Tiwari V M, Wahr J and Swenson S (2009) *Geophysical Research Letters* 36: L18401, doi:10.1029/2009GL039401.

Wada Y *et al.* (2010) *Geophysical Research Letters* 37: L20402, doi: 10.1029/2010GL044571.

12-15 September, 2011
Yantai, China

2011 LOICZ Open Science Conference

Coastal Systems, Global Change and Sustainability

www.loicz-osc2011.org

Organised by Land-Ocean Interactions in the Coastal Zone (LOICZ), hosted at the Helmholtz-Zentrum Geesthacht, Germany and the Yantai Institute of Coastal Zone Research, China

3rd iLEAPS International Science Conference

18-23 September 2011
Garmisch-Partenkirchen, Germany

Conference themes

1. Land ecosystem-atmosphere observation
2. Land ecosystem-atmosphere modelling
3. Innovative methods, ideas and challenges in ecosystem-atmosphere interactions
4. Human drivers and impacts of ecosystem-atmosphere interactions.

iLEAPS

The iLEAPS Scientific Steering Committee and the Karlsruhe Institute of Technology warmly welcome you to participate in iLEAPS SC2011.

www.ileaps.org/science_conf_2011

GLOBAL CHANGE IGBP International Geosphere-Biosphere Programme

Engaging the developing world

Almost two decades after the United Nations Earth Summit in Rio in 1992, global sustainability is an even greater challenge as the planet faces unprecedented pressures. Changing climate is likely to affect countries from the global "South" disproportionately: droughts in the Amazon basin and in Africa, and floods and landslides in Rio de Janeiro and Bangladesh are among a few dramatic examples of extreme climate events that have been broadcasted internationally. And climate change also has the potential to exacerbate poverty and inequality in such countries.

An important reason for the higher vulnerability of developing nations to climate change is their relatively lower adaptive capacity, which is linked to their socio-economic systems. Unfortunately, human and financial resources to cope with such changes are limited despite the potential for such change to suppress economic growth and prosperity. In most of these countries, the environmental agenda still is seen to be competing with the economic development agenda.

The concept of a green economy is an attempt to reconcile economic interests with environmental protection and social justice in order to mitigate the impact of global environmental change. But it will take effort to ensure that this new development model will catch on in the developing world. Success depends, at least in part, on a partnership between policymakers, non-governmental organisations, industry and the scientific community. And there is also a need for a dialogue between these stakeholders from the developing and developed countries.

An excellent opportunity for such a dialogue will be provided by the Planet Under Pressure conference organised by IGBP and the other global-change research programmes, to be held in March 2012 in London. The conference aims to discuss the state of the planet and explore solutions to move societies onto a sustainable pathway. The conference is timely not only because it precedes the 2012 UN Conference on Sustainable Development – Rio+20 – but also because it is likely to bring to the centre of the debate issues pertaining to collective action and environmental justice. Notably, the conference is aiming at 40 percent representation from the developing world, and a strategy has been put in place to achieve this goal.

The scientific organising committee of the conference has set up a working group for engaging developing country scientists; the group consists of both young and senior researchers with a range of expertise and representing the developed as well as developing countries. The working group has already contacted regional networks, national academies and other organisations from developing countries to encourage participation in the conference.

An important service being provided is mentoring to those from the developing world who would like guidance in preparing abstracts and developing presentations for the conference. Mentors will provide advice and feedback on both the process and content of abstracts for session proposals and/or presentations, and will help the mentees apply for travel funds. They will also meet the mentees that come to the conference, and introduce them to others.

IGBP and its sister programmes recently sent out a call to their scientific steering committee members to encourage them to serve as mentors. The response has been good, and the working group on engaging developing-country researchers is following up actively. Mentoring should not take much time from the individuals that agree to participate, but it may confer substantial benefits to the mentees, to the conference and to the efforts to build truly global networks.

Many scholars from developing nations deal with financial constraints to travel abroad to attend conferences. In many cases, only those who have contacts with established researchers end up attending. The working group is aware of this, and is exploring options to minimise it. One option, for example, is to tap into the network of IGBP national committees to cast the net wider than usual. A subset of the conference organisers is also working to secure adequate funding to support the attendance of developing-country scientists.

Another strategy is to tap into the experience and information gained from relatively recent initiatives seeking to draw in scholars from the developing world. For example, the 2009 workshop in Brazil entitled "Impacts, Adaptation and Vulnerability (IAV): Research Needs and Priorities for Developing Nations" was able to gather 89 researchers, mostly from developing nations. And the National Adaptation Programmes of Action (NAPA) of the United Nations Framework Convention on Climate Change (UNFCCC) could be used also as a means of engaging scientists and policymakers from developing countries – this programme focuses especially on the least developed countries.

The goal of engaging almost a thousand scientists from the developing world is ambitious to say the least. But the progress so far has been encouraging and this endeavour warrants more sustained effort.

PATRICIA PINHO is Science Officer at the IGBP Regional Office in Brazil.

CARLOS NOBRE is the Chair of IGBP's Scientific Committee, and the Coordinator of Policies and Programs in Research and Development at the Ministry of Science and Technology in Brazil.

PLANET UNDER PRESSURE

2012 MARCH 26-29 LONDON

A major international conference to provide scientific leadership towards the 2012 UN Conference on Sustainable Development – Rio+20

Deadline for abstract submission: 19 August 2011

— Organised by the global-change research programmes of the International Council for Science —

GLOBAL CHANGE IGBP International Geosphere-Biosphere Programme

DIVERSITAS

IHDP

WCRP World Climate Research Programme

and their Earth System Science Partnership

SCIENCE • POLICY • DEVELOPMENT • INVESTMENT
INDUSTRY • ENGINEERING • TECHNOLOGY • MEDIA

www.planetunderpressure2012.net