GR^2 : A GREEN RESOLUTION

FACULTY OF AGRICULTURE FOOD & NATURAL RESOURCES

THE UNIVERSITY OF SYDNEY

We are putting the right people in the right place to develop models and test strategies.

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WRITTEN BY TESSA COPLAND AND LUCY BUXTON

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DESIGNED BY CHRIS ANGWIN

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CONTENTS

PREFACE

The world has changed. The knowledge, methods and wisdom that have served land managers for generations are being revised at an ever-increasing pace.

If future generations are to thrive, we need to approach agriculture with fresh perspectives and an open mind.

With our colleagues at the University of Sydney we are forging a new path of ecologically sustainable development.

The Faculty of Agriculture, Food and Natural Resources is one of the most interconnected of all the University of Sydney's schools and faculties. This interdisciplinary approach is universally regarded as crucial to meeting the challenges of production and ecological sustainability.

GR^2 : OUR GREEN RESOLUTION

GR^2 is the faculty's Green Resolution. It is the second wave of thinking after the Green Revolution of the 1970s – a movement that helped feed the world's people, but at an environmental and socioeconomic cost that is clearly unsustainable. This next phase might be called a 'green resolution'.

We need a new paradigm, where agriculture, ecosystems and societies are one system. Where benefits gained in one area recognise consequences for others. It must lead to win–wins, rather than sacrifices. And we must act on it more quickly: we have less time to find answers.

The issues facing the world shape our work in agriculture and the environment. By 2050 we need to produce twice as much food and of better quality, using less land, less water and less energy. At the same time we must conserve biodiversity, restore degraded land and reduce greenhouse gases. We will have to do this with continually changing climates.

What drives us is education, research and training – all linking directly to these issues, and aimed at effective solutions.

We believe that staying connected to people and communities is the best way to keep a sharp research focus, and to positively influence policy at local, national and international levels.

Our rich history in agricultural research is now augmented by significant achievements in environmental research. Bringing together the goals of agriculture and sustainability will be the cornerstone of success in the next century.

This booklet shows you our vision, intent and activity. It is an invitation to join us and contribute to our community.

Professor Mark Adams, Dean

INTRODUCTION

FACILITIES

The Faculty of Agriculture, Food and Natural Resources at the University of Sydney is fast becoming one of Australasia's best housed and supported research groups. Outstanding facilities for plant growth include walk-in growth chambers with full environmental control – including atmospheric CO_2 – and farms and field stations where we can manipulate environmental factors in real time over different scales.

Our research and teaching community have access to some of the most sophisticated infrastructure for measuring and monitoring water supply. Staff and students work in laboratories of a quality on a par with the world's leading institutes.

New interdisciplinary research facilities are being built in Western Sydney and Narrabri, coupled with investment in scientific instruments and technical support of unrivalled quality.

TEACHING

'Friendly, welcoming and nurturing' is how people commonly describe our approach to students and visitors. That will not change. The faculty is as multicultural as Australia. Students enjoy a rich academic experience and a wide range of teaching modes – from intensive, small-group study to independent field-based exploration.

For a small faculty, the breadth and depth of our formal courses are substantial. Students have ample opportunity to explore their interests and become adept in key areas.

Our staff are committed teachers. They continually upgrade their degrees and units of study to reflect a diverse and dynamic world.

COMMUNITY ENGAGEMENT

Every year we host students, professionals and community interest groups in a range of settings. For example, we work with the Australian Government's program for engagement with countries in our region. We also offer tailored academic programs and skills-based training for people from as far afield as Africa and South America.

One of our most important links is with Australian communities in NSW and beyond. Each year we run workshops, field tours and community forums. These are all part of learning, and of refining our research and education programs.

RESEARCH AND EDUCATION PARTNERS

No university or faculty can operate in isolation. Our partnerships span Australia and the globe, but are always built on the foundation of significant research and collaboration.

You will find our staff and students in leading institutes in Europe, North America, Asia and many other places. Strong partnerships ensure our undergraduates and postgraduates are as at home in New York, Buenos Aires, New Delhi or Vientiane as they are in Sydney.

We offer students education, training and experience that will set them up for their place in the world. Finding our graduates in financial centres, research institutes or farmers' fields in Ethiopia comes as no surprise. Wherever they end up, they carry with them core values of lifelong learning and a practical approach to their work. We are delighted that so many return to the faculty to continue learning or contribute to educating the next generation.

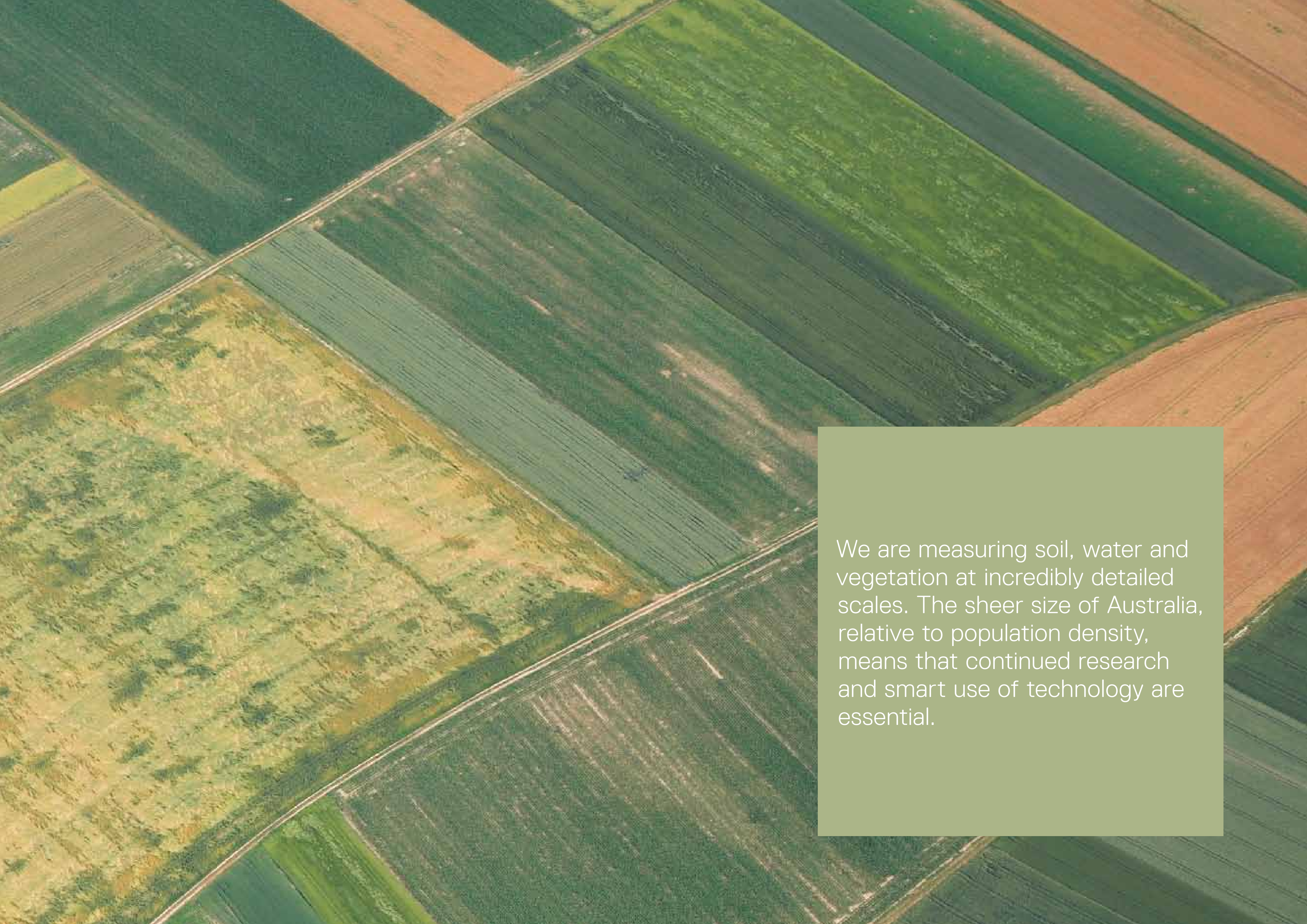
IS TIME ON OUR SIDE?

The world faces shortages of water, food, soil. In the next 40 years these may reach crisis level. Worldwide, groups like ours are taking up the challenge and recognising that time is of the essence.

Education, research and training are the closest we have to the answer – but we can't do it without you.

We invite you to join us.


What's out there?



We are measuring soil, water and vegetation at incredibly detailed scales. The sheer size of Australia, relative to population density, means that continued research and smart use of technology are essential.

CARBON

If we are to address changing climates, a crucial first step is to understand carbon's role in soil.

Carbon is life

Carbon is the main building block for living things, and a vital element in soil. It helps create soil structure, providing habitat for diverse organisms, preventing loss of nutrients and improving water retention. More importantly, it sustains microbes that recycle dead matter into nutrients, for uptake by the plants that feed the world.

Loss through human impact

Human activity has caused massive losses of carbon from soils. Land clearance and burning remove topsoil, while tillage and drainage expose organic matter to oxidation.

Around the world, fertile soil is being lost faster than it can be replenished. Since Europeans arrived, Australia has lost three-quarters of its soil carbon. The country could face significant challenges in carbon trading schemes and as an agricultural exporter.

Finding ways to reduce the damage, rehabilitate soils and maintain soil carbon is a high priority for research scientists in the faculty.

How soil works

How carbon interacts with soil–plant–microbe systems is poorly understood. In fact, at a time when the world's burgeoning population urgently needs better soil for better crop yields, some of the sharpest scientific minds are tackling fundamental questions about soil.

Professor John Crawford, former chair of the UK's Agri-Food Committee and inaugural Judith and David Coffey Chair in Sustainable Agriculture, hopes that by examining the complex relationships in soil, researchers can put forward some simple rules about how it works.

'We need to understand the interactions as part of a dynamic, living system. Soil science hasn't delivered the results that the next green revolution needs.'

Integrated research

Traditionally, agricultural scientists have tended to address problems in isolation – adding phosphorus, using tillage, applying pesticides. We are now learning that this can generate new problems. For example, adding fertiliser can suppress the natural processes that supply nutrients in soil.

Today, the faculty is in the vanguard of a new approach. We are in the unique position of having a world-class multi-disciplinary team under one roof.

To fathom the systems within soil requires expertise in chemistry, physics and biology. This knowledge must then be put into a spatial context. Scientists with wide-ranging skills are collaborating to gain a holistic view of soil's inner space – microbes, plants, structure.

'We're creating a vision of systems, to learn how the many processes interact as a whole. Then it becomes possible to manipulate the processes, with fewer interventions and fewer unintended consequences,' says Crawford.

Studying interactions

Soil is complex because it has co-evolved to support life. Using x-ray tomography, John Crawford is studying its structure, how this comes about, how it gets degraded, and the consequences for ecosystems.

A handful of topsoil holds billions of organisms and an intricate web of functions. The basis of human nutrition, health and survival lies in that volume of a few millilitres.

He has found that microbes, especially fungi, have a strong influence on soil particles. 'The structure is not static. The soil and microbe community are a living whole that changes and adapts over time, even without disturbance.'

Working with plant scientists, he is analysing how plants lose water and gain carbon, what happens in the roots, and whether this can influence the soil. Understanding these self-sustaining properties will help with plant breeding for water retention, maintaining ecosystems and adapting to changing climates.

Measuring soil carbon

Professor Alex McBratney is director of the Australian Centre for Precision Agriculture. He is developing an empirical model to predict how much soil carbon there should be at any point in the landscape, and what form it takes. An industrious group of PhD students are collecting data on rainfall, temperature, land use, climate change, topography and clay content, and relating these to soil carbon fractions.

'The differences in our data generate questions about the potential of different soil types, and also help with land management. The main cropping belt will probably have the least carbon, but there may be other areas that haven't lost so much.'

A global soil map

Professor McBratney also plays a leading role in mapping the world's carbon. The aim of this ambitious project (globalsoilmap.net) is to create a 90-metre-resolution global map showing how much carbon there is, and where.

'The driver is food security: identifying the potential of these soils for production. It's at the right scale for farms, catchments and local communities. We'll be ready for the climate modellers.'

The map will be invaluable at every level, from governments to farmers. Users will be able to tap instantly into the latest measurements. This research will revolutionise carbon auditing, and for the first time allow accurate soil carbon models to be integrated into climate change predictions.

Carbon storage: 20% by 2020

Accelerated land clearance and burning, use of fossil fuels and other activities all release CO_2, outstripping the ability of plants and soil to absorb it from the atmosphere. Australia's greenhouse gas emissions have surged by 82% since 1990.

The challenge for Australia is to increase current soil carbon by 20% by 2020.

'We have more CO_2 in the atmosphere, and less carbon in the soil. If you pump CO_2 out of a chimney at a coal-fired power station, you can't put it back. But we think you can reverse the loss of carbon from soil,' says McBratney.

His team is devising guidelines and affordable techniques for farmers to offset atmospheric CO_2 by sequestering carbon in the soil. Polluters would buy an offset in the marketplace, once there is clear evidence that carbon has been sequestered.

'We can show with reasonable precision that it has been stored, and in future farmers will be able to do this

What makes soil healthy?
Can we reverse the loss of carbon?
What are the economic issues in using soils and carbon?
We're seeking answers on many fronts, to propose an integrated theory.

themselves. We will advise them on increasing carbon content – and profits.'

Economic issues

The faculty is at the forefront of integrating the science of soils and carbon with economic and policy issues. Dr Niggol Seo plays a leading role in modelling behavioural and policy responses to changing climates, at an individual and global level. Working with Yale University and the World Bank, he has developed micro-econometric models to quantify the importance of geographic factors, including soils, in economic decisions related to climate. Eleven countries in Africa, seven in Latin America and several in Asia are collaborating.

'Economists view soils as incentives,' says Dr Seo. 'If a farmer is concerned with a certain grain, she/he may find the grain's yield to be higher on a certain soil type. But if she is concerned with increasing the family's income, she might find that particular soil type not so appealing. At a national level, we can ask whether soil resources are used in the most productive way. Otherwise, we are wasting our resources.'

A global policy for the next century

For the next 100 years or more, everyone will be asked to play a role in cutting back greenhouse gases, which are a primary cause of changing climate. At the same time, climate will constrain some activities, in and beyond the economic market.

Working with international centres of excellence, the faculty conducts research to foresee, negotiate and adapt to a future world constrained by carbon emissions and global regulations. A worldwide carbon penalty will aim to redirect how we use natural resources. With regard to soils, it will give more incentives for people to move from practices that are carbon-intensive, to those that conserve carbon.

To address the most pressing issues facing society, you have to look to agriculture for solutions. Our scientists are out in the field, answering the big questions.

WATER

One thing is sure: Australia faces water restrictions. But understanding the uncertainties about water will lead to wiser use.

Running on empty

Australia is the driest inhabited continent on earth. Recently, it was struck by one of the worst droughts since European settlement. And compounding the problem of natural variability is the scissor effect of growing demand and less rainfall.

Thirsty urban centres plumb reservoirs that are at record lows. With more mouths to feed, farmers step up irrigation. At the same time, changing climates are inducing a long-term drying trend over many regions.

Rivers, lakes and landscapes are under threat. In the cities, water shortages signal stark realities. Our ecosystems must be supported, but so must human life.

Impact on farming

Of the last 120 years, 51 were spent in drought. The effects on farming are often devastating, particularly for wheat producers. Water is the most pressing issue for landscape managers (farmer and government bodies alike), and in the face of changing climates, this is set to intensify.

Agriculture, the food-producing invention that has made or broken civilisations, is a high water user in arid Australia. A growing demand for food and fibre quality has added to water use.

Dr Willem Vervoort, an expert in hydrology and catchment management, has worked with the cotton industry to address the large but variable water losses below the root zone on fields with different soil types. Irrigators are now using new methods to tackle the problem.

A new project will forecast seasonal rainfall in a spatially detailed way, using data collected by Australia's 17,000 grain growers. Farmers will be able to adapt their management to changing water availability, and increase their yields and profits.

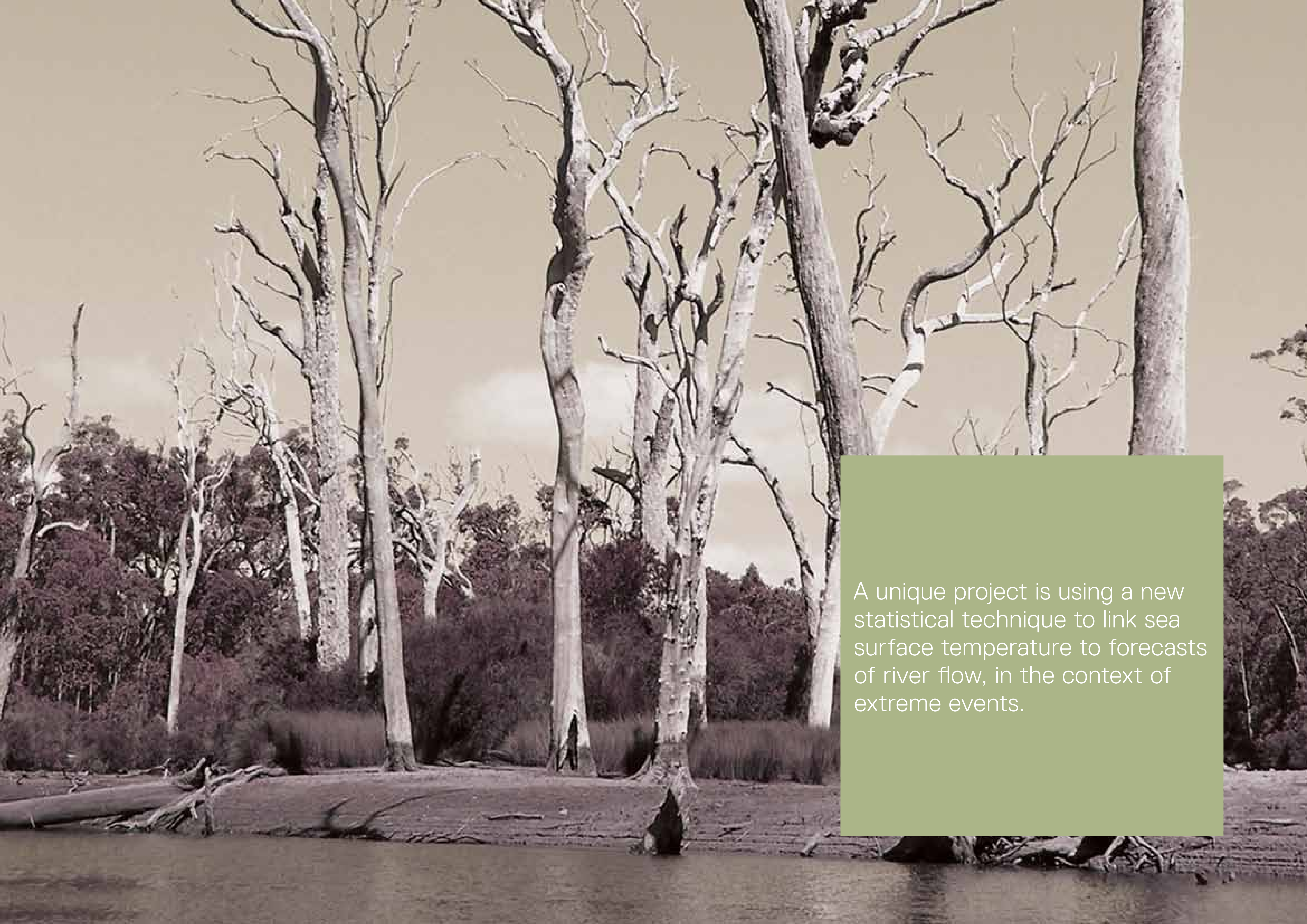
Harvesting water

Water is a precious resource and the process of collecting, storing and conserving it is vital for agriculture. But the demand on water resources is increasing – harvesting water upstream affects environmental and commercial processes downstream. Dr Vervoort and Dr Floris van Ogtrop have developed novel modelling techniques to give better forecasts of floods in arid and semi-arid systems. Irrigators along rivers in Australia are often dependent on floods to extract water under their licence agreement. However this extraction can affect downstream users, who also depend on the floods. Their research has supplied better forecasts on flows, for more adaptive management of crops and irrigation. This can increase water-use efficiency and reduce the impact downstream.

Management from measurement

Current water management is imprecise. Improvements can only come from ongoing, well-founded research. Effective training for farmers also depends on a sound knowledge of natural systems.

Advising Federal and local government, corporations and industry, the faculty's multi-disciplinary team pursues closely linked research on rainfall, evaporation–transpiration, and the water and carbon cycles.



A unique project is using a new statistical technique to link sea surface temperature to forecasts of river flow, in the context of extreme events.

In understanding what happens with water and how it is used, we develop the skills to make measurements on a continuum from the cellular level to the satellite view.

We extrapolate our results using mechanistic and statistical techniques, to make predictions for strategies such as:

– minimising water loss

– reducing fire risk

– managing cropping systems

– optimising water storage

– increasing carbon storage

– conserving lakes and rivers.

Forecasting: the uncertainty band

Because we are dealing with living systems, there is a large element of unpredictability. Water may be a finite resource, but the variations within dynamic natural cycles are myriad.

It is the nature of systems to be unstable. The challenge for scientists is to respond to the public expectation of a threshold number: exactly how much water do we need?

Dr Vervoort: 'There is no single answer, because we're studying a moving target – most ecosystems are not in equilibrium. Our challenge is to bring the variation within a band that we can prepare for.'

To narrow the margin of error and make more accurate forecasts, our scientists define a baseline of precision in the data. They can then scale upwards without increasing the error. Once they can pinpoint a realistic level of uncertainty, for instance that the forecasted rainfall is 500–700 millimetres, they can help land managers make decisions.

Space–time models

Management of Australia's landscapes is coarse in space and time. We irrigate whole fields despite differences in soil, and do not adapt to the temporal availability of water, such as during El Niño or La Niña periods. Without costly input data, current mechanistic models are inadequate for predicting in space and time.

Dr Thomas Bishop is building prediction models that combine available data, mechanistic models and advanced statistical methods. Land managers will be able to respond to natural variation in space and time, and predictions will be available for areas with no data. Researchers can pinpoint where the model fails, and then focus on producing better results and collecting more data.

'Farmers can already measure yield every 5 metres across their field, but they can't anticipate what will happen next year. With our models they can identify which parcel of land will get the best results for a wet or dry forecast, and how to manage the different parcels from season to season. It's adaptive management,' says Dr Bishop.

The impact of fire

Australia's capital cities collect much of their water from surrounding forest, and urban growth is boosting the demand. A warming climate compounds the issue, as it makes bushfires more frequent. Forests re-growing after fire consume more water than older ones, so if more of the forest near cities is made of young stands, less water can be collected for residents.

Dr Sebastian Pfautsch aims to give forest and water authorities a toolbox – to calculate the water used by forests of different ages. This would be used along with other strategies to reduce forest water-use.

His research is applicable to any city harvesting water from nearby forests, especially if fire plays a role (eg in California, southern Europe and South Africa).

From research to real life

To implement the strategies we put forward, farmers need highly technical skills. At the local level, people are more likely to invest in technology if we can present policies showing that it will raise their income.

The government's Cooperative Research Centres (CRC) help us take science to the rural community, but we also need thousands of graduates to pass on the skills and training to consultants, managers and farmers.

As society demands solutions to the water shortage, the faculty is laying down the science for astute management.

WHO SHOULD HAVE THE WATER?

The Murray–Darling basin is the food basket for much of Australia. Its lower lakes are also an iconic ecosystem. But it needs more water: native birds and fish are dying and the water is hypersaline. Among those competing for water are the irrigators who use it to produce export dollars, and those who want to save the unique species and landscapes.

Our job is to identify the trade-offs in decisions about the environment. For example, if the lower lakes are saved, food prices will rise. Where mining is affecting the water table, as in the Pilbara region, we are predicting the impact on water availability for surrounding and downstream vegetation.

FEEDING THE WORLD

Food production must double by 2050. Our best hope lies with science and economics of the calibre our faculty has achieved.

The food dilemma

The world's food supply is under pressure from a growing population and the assaults of changing climate.

It seems an impossible task: producing more, in the face of less water, limited land and unpredictable threats. To make the shift, farmers need new policies, techniques and training.

Growing food requires a blend of expertise: plant physiologists, horticulturalists, entomologists, plant pathologists, food chemists. These strands link to the environment (water, soil carbon and changing climates). And together they link to the supply chain, the economy and the policy of change.

The seeds of change lie in research programs such as ours.

A head start on adaptive measures

The faculty can already point to world-class achievements in plant breeding, nitrogen fixation and soil microbiology. We are now making advances in genetic analysis, nutrient cycling, safer insect control, and inoculation with biofertilisers.

Our international work improves food safety in developing countries by reducing the reliance on pesticides and preventing the use of unclean water. This in turn improves people's health, and increases the financial return to growers and their families, helping them out of poverty.

Plant breeding

The Plant Breeding Institute has achieved outstanding results with both rust-resistant and drought-tolerant wheat lines and cultivars, and other crops for dryland agriculture. To develop new cultivars that perform under even tougher conditions requires an ongoing commitment to this important research.

Using the latest technology, our new integrated breeding schemes are an effective way to increase rates of genetic gain. If combined with water-conserving practice, the new wheat cultivars will help to stabilise production in a changing environment.

Crop disease and biosecurity

Rust fungi pose a high biosecurity threat because they can travel long distances and build up rapidly, and those that attack economically important plant species are very damaging.

In 1973 a single epidemic of wheat stem rust in south-eastern Australia caused some $300 million in damage. Recurrent stripe rust epidemics in the Middle East during the 1990s provided graphic evidence of the huge impact of these pathogens.

For over 90 years, the University of Sydney has been studying the genetic control of rust diseases – an approach that is increasingly seen as the most sustainable way to protect crops.

Monitoring wheat rust in Africa

Professor Robert Park leads an international team monitoring wind trajectories to track the international spread of rust pathogens. The program is funded by the Bill and Melinda Gates Foundation, who are also funding

In the past five minutes, another 797 people have entered the world. Providing enough food will take a radical shift in how we farm.

the Plant Breeding Institute to train people from Africa in sustainable rust control.

Using GPS technology, the team is also developing a web-based global wheat atlas, identifying when and where wheat is being grown. The aim is to set up a global reporting system on the location and types of rust. This research will help people all over the world better manage their crops.

'In protecting crops we're addressing a dynamic environment. Plant disease outbreaks are dictated by climatic conditions, and wind patterns determine pathogen migration pathways,' says Professor Park.

Growth: China and India

Professor Richard Trethowan is a world leader in wheat breeding, with extensive experience in applying molecular technology.

To improve the stress tolerance of wheat, he is using a combination of marker-assisted selection for simply inherited characteristics, and new breeding schemes that integrate advances in genomics.

China and India are the focus of this research. These countries are ranked one and two respectively in global wheat production. But water for agriculture is increasingly limited, while populations continue to grow. Producing more food with less water is the great challenge facing both countries, and genetics will provide part of the solution.

The soil genome

Our soil scientists and microbiologists are studying the genetic make-up of soil, to develop a DNA profile of the soil and its processes – the soil genome. The technology needed for such testing is still at the research stage, but we have already made advances.

Important soil processes, such as the cycling of carbon, nitrogen and phosphorus, can be genotyped. We can identify genes in the soil that typify processes such as nitrogen cycling and fixation, or phosphorus and sulphur mobilisation.

In future, expression of these genotypes can be matched precisely to the needs of crop plants. For example, nitrogen and phosphorus could be mobilised to match the plant's needs during growth, rather than after harvest.

From the field to the table

Feeding the world is not always about producing more. Efficient delivery of high-quality produce is just as important. Wastage accounts for about 25% of production costs, often because of problems with storage, handling and over-supply. To meet the demand for year-round fruit and vegetables, growers produce out of season. This puts stress on plants and reduces shelf life.

As an example of our work in this field, Dr Jennifer Jobling's research into postharvest quality of packaged spinach and rocket has shown that shelf life can be doubled if the storage temperature is managed well. This makes for less waste along the supply chain.

Health and nutrition

The number of people who eat an unhealthy excess now exceeds those who are hungry. Obesity, type 2 diabetes,

certain cancers, and cardiovascular and other diet-related diseases place a huge burden on the community.

Research on crop improvement is now turning to traits that affect quality, to improve processing of raw materials and deliver health benefits. Professor Les Copeland is interested in links between agriculture and health, in particular grain quality, and cereals with modified polysaccharides for better control of diet-related diseases.

But as he notes, 'Understanding the human element and driving behaviour change is also a priority, particularly if better health is considered important in ensuring food security.'

Nitrogen fixation: reducing fertiliser needs

Whereas carbon comes free, nitrogen has to be added as fertiliser. Higher oil prices are raising fertiliser costs. In addition, agrochemicals increase the farmer's carbon footprint. Finding alternatives is crucial.

One way to add nitrogen is by growing plants such as lupins, clover and soybeans. In 1995 the faculty established the SUNFix Centre to promote research and teaching in nitrogen fixation. We are improving the nitrogen-fixing properties of legumes and pulses, to replenish the soil during the fallow cycle.

Efficient rice-growing in Vietnam

Using microorganisms isolated by colleagues in Vietnam as natural fertilisers, SUNFix has provided quality control for the inoculant bio-fertiliser BioGro, which can improve yield and efficiency of nutrient use in rice.

In 2008, SUNFix director Professor Ivan Kennedy was the co-recipient of a US$200,000 grant from the World Bank, to extend BioGro to 1000 farming families in the Mekong Delta and southern Vietnam. This product reduces the need for urea by up to 50%, while increasing plant vigour and yield.

Other benefits of the program include: improving livelihoods through local production of BioGro; increasing farmers' profits; reducing environmental harm from the greenhouse gas nitrous oxide; ensuring greater food security.

Similar products have potential for wheat-growing in Australia.

Safer pest control

Because insects evolve quickly, growing crops for the world requires better pesticides. Organic methods are too labour-intensive and risky for the third world, and grain stores have to be protected. Less than 10% of total food production can be feasably achieved organically with the techniques available today.

In Australia and South-East Asia farmers use pesticides widely because of very good cost benefit ratios. The challenge is to protect the environment at the same time as these agrochemicals are applied.

Ivan Kennedy: 'In agriculture, we are finding softer ways to control pests and weeds. For example in genetically modified crops, we have the advantage of introduced genes that code for naturally occurring toxins to insects, which reduces the need for chemicals. In our own work, we have shown the environmental benefits of using certain types of

GM crops. The modified plants often reduce the need for harmful residual chemicals.'

Chemical test kits

For non-GM crops, monitoring agrochemicals is important for environmental protection – for instance to prevent leaching into river systems, or to show that water is safe for drinking or for aquaculture. To help farmers choose and manage chemicals better the faculty is developing test kits for farmers to use. Our postgraduates are gathering data and doing risk assessments that can be used for better management in Australia, China and Vietnam, where some kits are also in use.

Better policy, less poverty

Feeding the world's poor takes much more than getting the science right. Before they will adopt new farming practices, people need stable government, access to markets, credit, and property rights.

Agricultural economist Dr Greg Hertzler works in Pretoria, training postgraduates from all over Africa. 'Poor people must feed themselves and escape poverty through agricultural development. But for this to happen we need to create good policies.'

As an example, he is working with a PhD student from Sudan to manage communal fisheries. 'Their fisheries are over-exploited. The only way for these families to feed themselves is if the policies are improved.'

The faculty is also involved in preparing a digital soil map of Africa for the first time (see page 13). Better knowledge of soil properties will allow greater productivity from African soils and contribute to better environmental management.

Policies are also the focus for Dr Paulo Santos. His studies include: the impact of formalising property rights for land in Laos, and of distributing livestock to poor people in the highlands of South-East Asia; the benefits of fertiliser subsidies in Malawi; the importance of social networks and discrimination in labour markets in South Africa.

'There is still much we don't know about why poor people remain poor and what are the best ways of addressing the root causes of poverty – evidence-based policy is as needed around the world as in Australia.'

A NETWORK OF GRADUATES

Postgraduates do over half the research in Australia, so it's important to involve them in projects that are breaking new barriers. Our former students are working on food production around the world, in universities and in villages. They're passing on tools and expertise, and collaborating with the faculty on further research.

CHANGING CLIMATES

In a parched land beset by extreme weather events, our scientists are preparing a blueprint for survival.

Impact on Australia

Of all the developed nations, Australia stands to suffer the most from climate change. Facing increased drought, fire, intense storms, erosion and loss of species, it has become a real-world model of changing climates.

The margin of usable land is narrowing. Plant health and crop yields are vulnerable to changes in temperature, rainfall, wind patterns, water supply and the spread of disease. Economically, a hot, dry climate by 2050 would be very damaging. In the shorter term, without new, more resilient crop species Australia may not remain a global exporter of cereal.

The magnitude of climate change, its pace, and the possibilities for adaptation are uncertain. Australian farmers are excellent risk managers, but they urgently need resources and skills to meet the challenge.

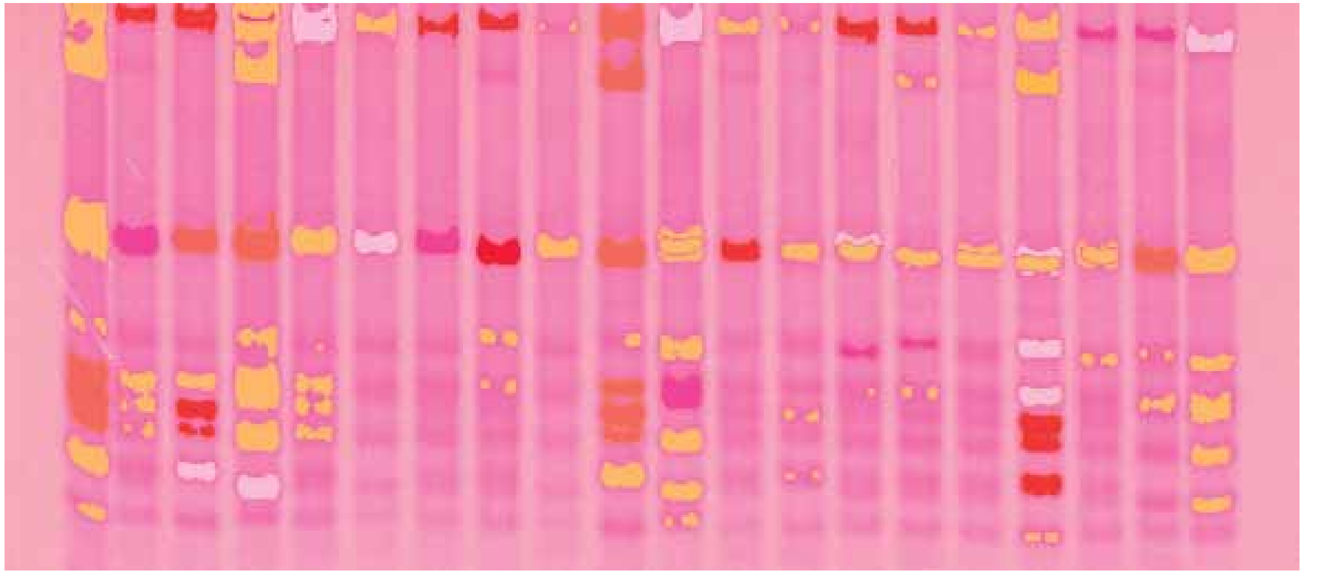
Sustainability requires innovation

Increasingly, people will look to science for robust strategies of adaptation.

In Australia and around the world, the faculty is putting forward new ideas – about plant function, yield prediction, crop development, water-use efficiency, food security.

We collaborate internationally with geologists, climatologists and other scientists, on projects ranging from the biosecurity of wheat to showing how Earth's vegetation and climate have interacted and changed over millennial timescales.

We offer a unique combination of expertise and backgrounds, and potential ways forward that individuals alone could not develop.



Our plant breeders, agronomists, plant physiologists and environmental economists are addressing climate change from many perspectives.

For example, our economists are looking at:

– how good managers make choices, so that we can create models of the future of agriculture
– which areas of Australia may abandon wheat-growing, or may adopt it
– devising coherent public policy
– the impact on developing countries.

Our research is already yielding results, such as the first economic model of how individuals' behaviour adapts to changing climates.

Australia may top the list for CO_2 emissions per capita, but it can also lead the way to a low-carbon future.

Drought-resistance vs. productivity

The Intergovernmental Panel on Climate Change (IPCC) projects an increase in dry days over most of Australia.

Plant scientists must breed a new generation of drought-tolerant species that are adapted to high CO_2 concentrations – but this is no simple task. Drought tolerance is often linked to lower productivity, so the challenge is to come up with breeds that are still commercially viable.

Dr Peter Franks holds a Future Fellowship, awarded to outstanding researchers to study areas of critical importance. He and his colleagues are addressing the urgent need to better understand the effects of water stress. Their goal is to mitigate the trade-off between drought resistance and productivity, by producing 'hydrologically optimised' plant varieties.

Fossils point to the future

Palaeobotany is one of the oldest plant sciences, but by combining it with the latest physiological and molecular techniques, our researchers are breaking new ground.

At the head of an international team, Dr Franks is looking at the co-evolution of plants and climate, and reconstructing how ancient plants functioned and adapted to rising CO_2 over time. This will guide our response to future needs.

'We know that plants do better with more CO_2, but when it's linked to rising temperatures and drought, how will they respond in future?'

Combining historical data on fossils with functional information from living plants, he is studying how stomata on the surface of leaves respond to CO_2 by altering the balance of carbon gain and water loss.

The aim is to build a global, deep-time chronology of plant–gas exchange capacity over the 450-million-year history of land plants. It will provide an unprecedented global perspective on the relationship between changes in atmospheric CO_2, global vegetation and climate.

Selecting for drought resistance

This work underpins our plant-breeding program. For example, if we can predict how plants will function with water stress, we can develop new wheat varieties that are more water-efficient. Advances in DNA technology make it possible to find linked traits for drought – such as stomata that open longer under water stress.

Our researchers have identified genes that change stomatal function, but there is more work to do before they can produce a new variety of wheat.

Plants link carbon and water cycles

Dr Margaret Barbour (also a Future Fellow) is examining how CO_2 diffuses within leaves. Early results suggest that genetic variability in this trait has the potential to improve water-use efficiency in cereal crops. This work is advancing knowledge of plant response to changing climates, and will provide tools for plant breeders to develop more water-efficient plants.

She is also studying the trade-off between carbon gain and water loss in natural ecosystems. Using naturally occurring variation in stable isotopes of carbon, she has shown that the photosynthesis–respiration link varies among forests. This has profound implications for forest–carbon balance.

Carbon sinks

Dr Barbour has worked with scientists from Scotland, France, Germany, Israel, the United States and New Zealand to re-interpret global mass balance models of stable oxygen isotopes. These predict regional carbon sources and sinks – an important component in understanding and reducing global carbon emissions. New understanding of the role of soil microorganisms has improved predictions, particularly in the tropics. Accurate prediction of carbon sources and sinks has major environmental, political and economic implications as we attempt to combat climate change.

The research program aims to help managers, industry groups and agri-businesses prepare for unavoidable impacts.

With the expansion of our premises to the Australian Technology Park, we now have labs of a quality that we've been dreaming of, and many talented postgraduates to work in them. Much of the groundwork can now come to fruition.

MANAGING AUSTRALIAN ECOSYSTEMS

Our integrated expertise is the perfect match for the challenge of sustaining ecosystems.

Challenges on all fronts

Natural and agricultural ecosystems are vulnerable to numerous threats – from drought and bushfires, to urban growth and outdated farming practices. How can we protect our land in so many arenas while keeping it productive?

There is no single answer. Indeed, to propose long-term solutions, we need a more thorough understanding of our environment.

The multi-disciplinary advantage

Sustainability requires more than just isolated facts. Much is known about soil formation, for example, but not in the broader context of ecosystem structure, function and processes. What is needed is evidence-based information on the gamut of processes, from plant–soil–atmosphere interaction to water use and rainfall variation.

Our faculty does integration very well. We are ideally placed to fuse disciplines and put forward a new framework for land management.

Measurement is a key strength, and the density of the data we collect is phenomenal. One challenge is variability – for example, disentangling the impact of human activity from that of natural cycles of rainfall and drought.

As our team gathers multiple measurements at different scales (eg from leaf function to landscape-scale vegetation distribution), we are building a picture of how it all fits together. This degree of sophistication is essential for the development of robust policy.

Fire

Every terrestrial ecosystem in Australia is affected by fire. It can wipe out an entire resource such as mountain ash forest, which takes many years to establish. It can alter populations of native birds and animals, and it changes the nutrients in the soil.

The toll can be devastating. In the Victoria bushfires of February 2009, 173 people died and 414 were injured; 450,000 hectares were burnt, and many of the state's koalas, kangaroos, birds and other wildlife were lost. These fires followed the even larger fires in 2003 and 2006/7. While not as devastating to human life, they had massive impacts on rural communities, and will continue to affect the water yields from rivers for decades to come.

Residents, landholders, conservationists, firefighters and policy makers all want better fire protection and land management.

We have to be much smarter about managing land. The new direction is in understanding how systems work.

Led by Dr Tina Bell, our research program in Victoria and New South Wales is pushing Australia to the international forefront of fire research. 'Fire is one of the most powerful integrating processes in natural ecosystems. It affects the atmosphere, soil, water and productivity. By introducing fire into the undergraduate program, we are raising awareness and preparing the next generation of fire managers and researchers.'

Measuring volatile compounds in smoke

The smoke created during bushfires has many components – from harmless water vapour, to fine particles that make us cough, to harmful but invisible chemical compounds. One of our cutting-edge projects is to analyse some of the hundreds of volatile compounds.

The aim is to learn which volatiles are released from different fuel types (eg eucalypts compared to pines, leaves compared to bark), and how these might affect human health and agricultural and forested systems.

In addition, from collaborative research with the University of California, Berkeley on the effect of smoke on grapevines, we hope to pass on useful information to land managers, grape growers and health advisers. As pressure mounts to increase prescribed burning, we want to pinpoint where and when land managers should burn to reduce fire risk, with the least disruption to producers and the community.

Semi-arid landscapes

Around 75% of Australia is semi-arid, much of it of low productivity and open to the boom-and-bust of climate extremes.

The ability of native vegetation to thrive in such conditions can give insight into better management of Australia's agroecosystems. We need to learn more about the ecophysiology of native plants, and exactly how they respond to the large variations in temperature and rainfall. The Pilbara region in north-west Australia offers a natural research laboratory: a reservoir of genetic information going back two million years, where there is enormous variation in properties that allow for survival.

Our results will help plant breeders explore species suitable for land that is currently under-productive.

Box-gum grassy woodlands

Because of grazing and clearance, less than 3% remains of the native woodlands that extend from Queensland to Victoria. In a partnership with the Federal Government, The value of ecosystems goes far beyond the production of food and fibre. We are promoting the concept of ecosystem services, for instance through payment for carbon sinks.

Peter Ampt has identified practices that increase habitat for endangered species, while maintaining and improving farm profitability. Another benefit is increased carbon in soil and plants. The next steps are to offer training and resources for adopting these novel techniques, and to monitor the impact.

Nitrogen-fixing trees for fertility

At our research properties near Cooma and at Camden we will examine how agroforestry can improve soil. One focus is on the nitrogen-fixing native casuarinas, which could be planted on a 10-year cycle to rehabilitate land, harvested for biochar, and used for carbon credits.

Such initiatives could restore production to vast tracts of degraded land.

Mining and the water table

For scientists, iron-ore mining in the Pilbara has created a real-life experiment in how trees, grasses and shrubs respond to lower ground water.

We are learning how much water native plants need to survive, how much they take from the system and where they draw their water from. That determines what is available for wildlife and other users. This need–use analysis is important for land management, particularly where there are only one or two rainfall events a year.

Variations in carbon

Two projects are yielding data on how different landscapes function in variable conditions.

At Pilbara mining sites, massive amounts of water are being moved around the landscape each day. Using eddy covariance towers, Dr Robert Simpson is continuously measuring fluxes of carbon and water downstream, to understand how de-watering affects the system as a whole. The integration of all processes over large areas, combined with smaller (ie individual tree) measurements of plant physiology, is a powerful tool to quantify the effects of mining on an ecosystem scale. We need to determine whether the effects are due to mining or to natural variation.

Similar information is being gathered in the sub-alpine catchments of south-east Australia. Farmers in the high country need to know with some certainty how crops will respond to variable temperature and rainfall.

Data on the flux of greenhouse gases in soil shows that alpine areas are a strong sink for atmospheric methane. In an appropriate legislative framework, this could become a resource for farmers.

Data networks

The faculty is collating data to monitor fluxes of water and CO_2. This feeds into the Ozflux national network of stations, which aims to expand the use of eddy covariance measurements into all Australian biomes. 'We can start to say, if precipitation increases by X, what does it mean for different areas of soil?' says Robert Simpson.

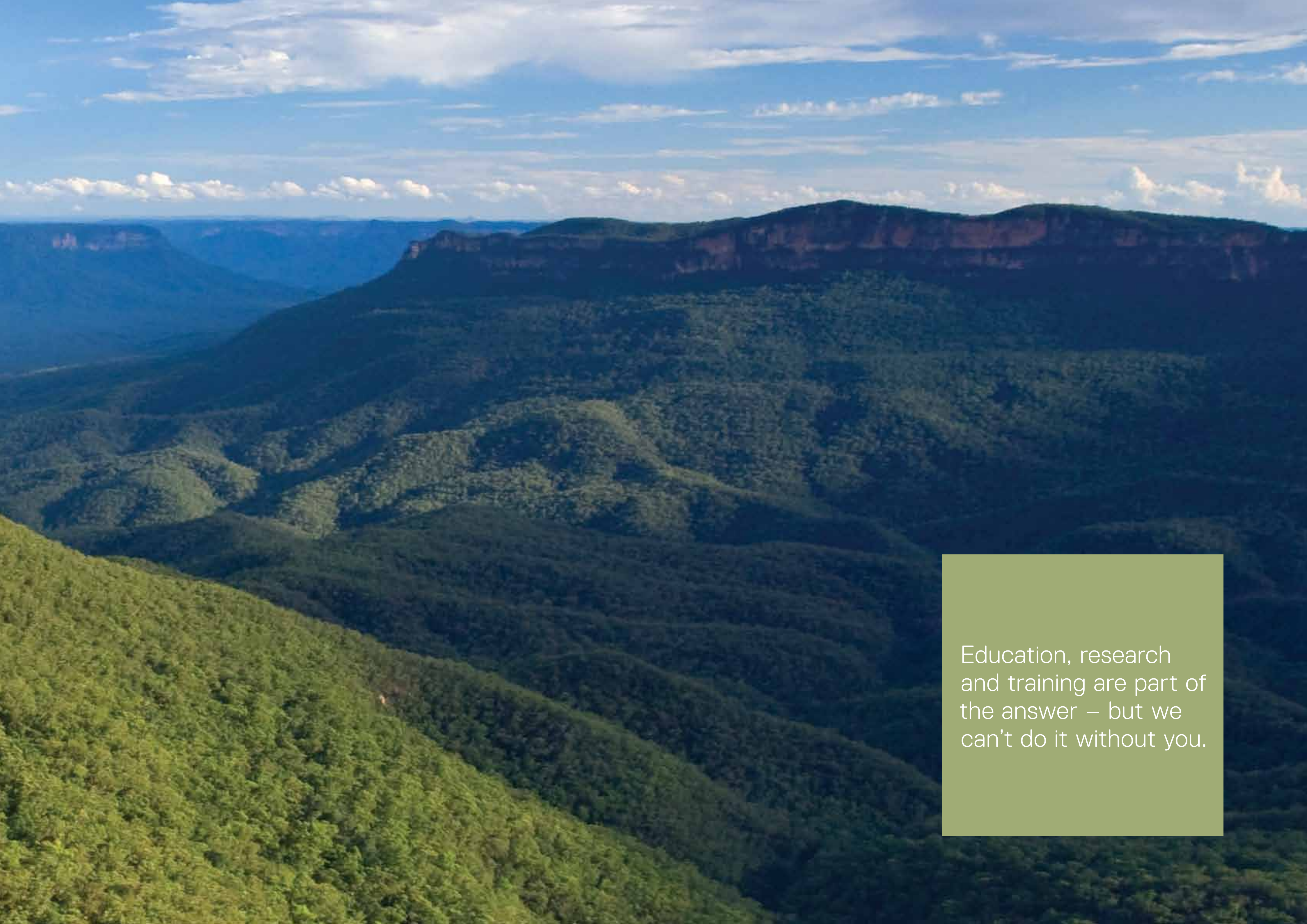
The network is linked to stations around the world. In the United States, information is recorded with the same parameters, forming a global open-source database. With similar networks, this is used by the IPCC (Intergovernmental Panel on Climate Change) to drive and constrain global climate models, as well as develop warming scenarios.

Reaching the community

Community engagement is always part of our research and learning. We are committed to working with local partners through a range of programs:

- To address the fire problem, staff are working with the Rural Fire Service on practical courses and field work
- Graduate researchers make presentations to the Country Fire Authority on how our research fits in with their role
- We hold forums for graziers, farmers, naturalists and catchment managers
- At Coolringdon in NSW we offer community programs on sustainable grazing and farming decisions
- To assist the kangaroo industry we have linked remote farmers with commercial harvesters, and recommended strategies for increasing the market
- With Landcare NSW we are building landholder networks to support agriculture and address social isolation
- We are working with the 'Wellington Working Farms' project in NSW. Local young people, including Indigenous Australians, learn about farming and conservation activities.

Worldwide, groups like ours are taking up the challenge and recognising that time isn't on our side. The world faces shortages of water, food, soil. In the next 40 years these may reach crisis level.



Education, research and training are part of the answer – but we can't do it without you.

FACULTY OF AGRICULTURE, FOOD & NATURAL RESOURCES
Dean: Professor Mark Adams
T +61 2 8627 1000
F +61 2 8627 1099
E dean.agriculture@sydney.edu.au
sydney.edu.au/agriculture

FACULTY OF
AGRICULTURE
FOOD & NATURAL
RESOURCES

THE UNIVERSITY OF
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