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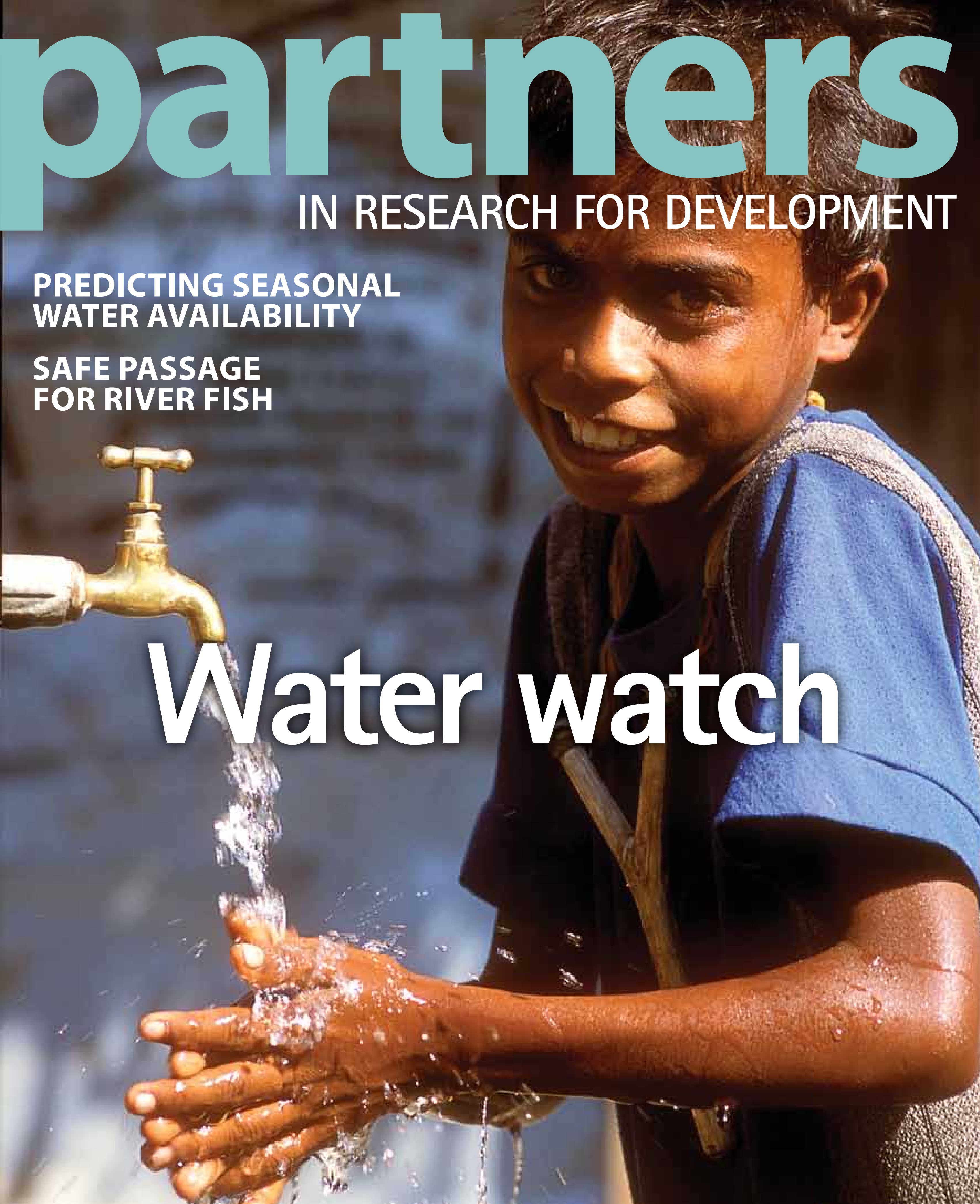
IN RESEARCH FOR DEVELOPMENT

PREDICTING SEASONAL WATER AVAILABILITY

SAFE PASSAGE FOR RIVER FISH

Water watch



Water management and food security

Food security has dominated debate about development assistance ever since the food crisis of 2008. That crisis reminded the world that progress to eradicate hunger and extreme poverty can be easily undone.

A number of factors—drought, low reserves of food, high energy prices and changing emphases on crops sown for biofuels rather than food—converged to create the crisis. In the debate and responses that followed much was achieved to avert the crisis deepening.

Responses from the global community included emergency measures and longer-term initiatives to boost food stocks and refocus on the importance of increasing agricultural research and development (R&D) after a prolonged period of expenditure reduction. Much is still to be done to lift more than a billion people out of poverty.

Of all the factors that created the crisis one is likely to present the greatest challenges in the future—water management.

About 70% of the world's extracted freshwater resources are used to grow food. Demand for this resource is growing. Pressures from industry, urbanisation and environmental management are forcing farmers to compete for water. Changing climate conditions and prolonged periods of dry or drought are reducing water availability. Population growth over the next 40 years, with another two billion mouths to feed, will only amplify the pressures in this complex mix.

By 2025 global water use is expected to double. Demand for water is not isolated to regions or countries either. Where water courses and basins cross national boundaries—such as the Mekong River, which flows through half a dozen countries—water management becomes crucial.

Saving water and better managing its use have never been more important for agriculture. Diminishing agricultural R&D expenditure over the past two decades shows how easily food production can be taken for granted. As competition for water increases agriculture will face more pressure to further cut water use.

This presents a challenge for farmers and scientists, who will be expected to continue to produce more food, even as competition for water intensifies. Agricultural R&D is already responding to this challenge, learning how to better manage crops in dryland conditions, and how to manage and preserve water resources.

Australia has significant scientific expertise in managing drought and water shortages. ACIAR is sharing this expertise with a number of partner countries where water management is needed to combat dry or drought conditions and to ensure that available resources are not depleted. The flow-on benefits from ACIAR-funded research have saved an estimated 1,000 billion litres of water each year, with the potential to save another 2,000 billion litres a year in Australia.

Conflicts over water distribution in India are not new. Water allocations from the Krishna River, which flows through three states, have previously been determined by a disputes tribunal. The reconvening of a tribunal for water management has been supported by an ACIAR-funded project that has helped demonstrate the need for a holistic approach to managing the river system.

Water and irrigation management in China has also been advanced through ACIAR research. Two projects, one on irrigation management and the other on policy approaches to increasing the value of water, are now linking with AusAID projects on water management. These are helping farmers understand the value of water, which is supplied freely in many areas, and manage irrigation to their crops in a more timely manner.

Changes to traditional irrigation-management approaches in southern Vietnam are also being made through ACIAR-funded research. Poor farmers in the area had linked irrigation needs to rules and dates, such as the Tet holiday, that were experience-based. Research has shown that using less water, with applications guided by simple on-farm management devices, provides improved yields. In China too, changes in fertiliser and water management resulting from ACIAR-funded research have resulted in less water being used, reduced greenhouse gases and increased yields.

These and other projects covered in this edition of *Partners* demonstrate that water management need not result in reduced yields, and that saving water is a vital component of long-term food security.

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Thirsty farms challenge India's

ACIAR is helping scientists and farmers manage water supplies that are stretched to capacity in India's food bowl, the Krishna River Basin

BY MELISSA BRANAGH-McCONACHY

Considered holy in Hindu mythology, the Krishna River has for centuries provided irrigation, potable water, cheap transportation and, more recently, electricity to the Indian people. But the 1,300-kilometre waterway—one of the country's longest—is stressed, with almost all available water allocated. When all water is allocated the river is said to be 'closed'; the resource exhausted.

On its way to the ocean, the Krishna River supplies water to 73 million people in the states of Maharashtra, Karnataka and Andhra Pradesh. But ocean discharge from the basin has decreased substantially over the past 20 years in the face of rapid urbanisation and irrigation developments. Economic progress and population growth have underpinned increased industrial and household demand, jeopardising water distribution to agriculture.

The need for efficient, sustainable water allocation has become even more critical in light of heightened inter-sectoral competition for diminishing supplies and environmental pressures.

Determined to find ways to meet demands while ensuring positive environmental and economic outcomes, scientists from Sri Lanka's International Water Management Institute, the Jawaharlal Nehru Technological University and the University of Melbourne have evaluated implications of various allocation strategies designed to improve water productivity in agriculture as part of a $1.4-million ACIAR project.

The original project, which ended in September 2009, has helped to shift the water management focus in the Krishna River Basin from a state-based mindset, motivated by local interests, to a whole-of-basin approach—the key to sustainable resource management.

Professor Hector Malano, head of the University of Melbourne's Department of Civil and Environmental Engineering, says while capacity building was not the main project objective it has enabled rival stakeholders to collaborate and understand each other over the life of the project—an achievement considered essential to progress.

"If you don't do accounting at the whole-of-basin level, you cannot get an accurate picture," Professor Malano says. "This has now been formally recognised by major stakeholders in India."

food bowl

PHOTO: MELISSA MARINO

A CHANGE IN THINKING

The decline in water volume in the Krishna River system was hastened by expansion of irrigation diversions between 1960, when water debates between the three riparian states began, and 2005.

Under a 1973 resolution passed by the Krishna Water Disputes Tribunal, the Central Indian Government offered the states monetary incentives for water capture that ignored impacts on the whole basin, compromising management efficiency.

The Krishna River Basin is quickly approaching a 'closing state', which implies all available water is fully allocated for most of the year. Flows out of the river, which originates in the Western Ghats watershed, have already ceased, mirroring the situation in Australia's Murray–Darling Basin.

It was this parallel that influenced the design of the ACIAR venture—a four-year undertaking that has shifted the way the Indian states approach management of this river to develop whole-of-basin models.

Fearful they would be forced to relinquish water shares, Professor Malano says the states were initially reluctant to provide data or participate in the project's execution. This fear was driven by the Government's reconstitution of the Krishna Basin Tribunal to negotiate allocations for the next five years.

"Basin-wide water demand is now double the total water allocated by the tribunal and irrigation needs are substantially higher than shares designated in 1969," he says. "The pressure to justify their water use has made the states, particularly downstream water users, very nervous because they are aware they are at risk of losing volume."

To help manage these concerns, the ACIAR project team first focused on understanding the river's sub-basins. It formulated individual hydrological, water allocation and economic models under a single framework, which were used to quantify surface and groundwater supply and demand from competing sectors: agriculture, domestic, industrial, power generation and environmental. Models developed for sub-basins were subsequently aggregated in state and whole-of-basin models.

MODEL FLOWS

The Resource Allocation Model (REALM) was used to calculate water allocation at the catchment level (Musi, Malaprabha and Upper Bhima), while statewide modelling was carried out using the Water Evaluation and Planning System Model (WEAP).

A social cost–benefit analysis found that although most of the water from the Krishna River system is used in agriculture (95%)—predominantly for rice and sugarcane production—it yields only up to 2 rupees per cubic metre, while the limited amount of water transported to the city for domestic use (3%) and industry use (2%) returns more than 50 rupees per cubic metre and 10 rupees/m^3 to household and industrial users respectively.

Researchers identified opportunities to increase the productivity of water use in agriculture through the development of alternative water allocation scenarios. At the sub-basin and state levels, results indicated cropping pattern changes would have the greatest impact in reducing water pressure, although agricultural returns would slump by 1–3%. Results showed that improving efficiency of water transfers throughout the system would significantly boost net present values.

"While the amount of water that feeds into Hyderabad (the capital of Andhra Pradesh) has decreased by up to 40% because it is being used upstream, a new paradigm has emerged in water-scarce environments, such as the Krishna and Murray–Darling basins, that focuses on moving water in the direction of greatest economic return: industry and urban industrial areas," Professor Malano says.

"Reallocation will favour the cities. However, the Indian Government also wants to guarantee food security, so improving water-use efficiency in agriculture is crucial and that will only happen if the system reveals water at its real price, not at its current subsidised value."

Like Australia's Murray–Darling system, Professor Malano predicts that a significant population shift from rural to urban areas will see Indian farms become bigger and more productive.

"As rice productivity is low, this will involve looking at ways to produce more per megalitre and trialling other crops to maximise water value," he says. "Water and electricity have been free resources so there has been no incentive to explore technologies to boost efficiency—something else the government has to change."

The project team has recommended crop diversification measures to meet urban needs,

PARTNER COUNTRY
India

PROJECT: LWR/2003/026: Water allocation in the Krishna River Basin to improve water productivity in agriculture

CONTACT: Dr Mirko Stauffacher, ACIAR RPM, stauffacher@aciar.gov.au; Professor Hector Malano, hectormm@unimelb.edu.au while minimising impacts on agriculture, improving system efficiency and introducing sustainable water-management practices in cities, such as harvesting rainwater and reusing wastewater. This approach would cost Indian society 6% less in net present value terms than appropriating water from the Krishna River.

But scientists acknowledge that, as cities within the Krishna River Basin grow, more water allocations will have to be shifted from agriculture. This would increase the shortfall in cropping upstream and place more areas under irrigation downstream, where wastewater from the city could be utilised. Further investigation is required to explore this opportunity.

The project has also provided the basis for improved water-cycle management to address downstream environmental impacts of watershed development programs.

"There will be trade-offs, but our assumption is that water-infrastructure costs to transfer water from other catchments to replace reduced flows would outweigh the benefits of such programs," Professor Malano says.

He says extensive stakeholder engagement is largely responsible for the shift to a whole-of-basin modelling approach, which he describes as "unprecedented in terms of combining hydrology and economics" to inform solutions.

Modelling efforts are now focusing on sub-catchment, sub-basin and whole-of-basin scales. The next phase, which begins in March, will apply the models to various scenarios to evaluate different options for real climate change adaptation based on predictions that by the end of the century, India will experience a 3–5 °C temperature increase, more frequent droughts and extreme flooding.

"Water reform takes many years, but we can expect economic progress will accelerate that process over the next decade in India," Professor Malano says. "We hope what we are doing will have an impact on allocated water shares determined by the Krishna Basin Tribunal." ■

Improving canal and groundwater distribution in Pakistan

In Pakistan's arid climate irrigation is a lifeline for agriculture, but the Punjab irrigation system—one of the largest in the world—is struggling to cope with present-day demands, resulting in water overuse and inequitable distribution.

The Punjab network is colossal: five major rivers and their tributaries feed the 37,000-kilometre lattice of barrages, canals, drains and tube-wells that irrigate an area exceeding 8.4 million hectares.

However the system, which accounts for 80% of the country's agricultural production, cannot withstand recent developments including an average 130% increase in cropping intensity, population growth, and changes in sociological and rural practices that have rendered its design obsolete. Excess seepage and wastage in the system, and inflexible canal water rights, have aggravated the problem.

The Punjab Irrigation and Drainage Authority (PIDA), set up by the Pakistani Government to operate and maintain the network, has attributed poor water-use efficiency of 35–40% to system constraints and management issues.

Analyses have shown that water volume and quality decline the farther water travels in the Pakistan irrigation system. The inequitable supply of surface water to tail-end users is closely correlated to diminishing crop yields and escalating salinity, while groundwater accessible to tail-end farmers is salty, with serious socioeconomic and environmental implications. Studies have confirmed that salinity alone is robbing Pakistan of about 33% of its agricultural production.

The Pakistani Government's 2025 vision for adequate, equitable, reliable irrigation supplies and enhanced agricultural productivity stipulates the need for investment in rehabilitation and system improvement. This outlook has underpinned policy reforms guided by PIDA, including conversion of irrigation infrastructure management into a multi-tier system involving farmer participation at provincial, canal command and distributary levels.

PIDA has also acknowledged the need for changes on the ground, citing a substantial gap in scientific information to help farmers conjunctively use surface water and groundwater.

In response, ACIAR launched a project in 2008 that aims to improve canal water and groundwater distribution to optimise crop production and manage salinity in irrigated landscapes. Due for completion in 2012, the $1-million project is being led by Charles Sturt University (CSU) in Australia, in collaboration with Pakistan's University of Agriculture in Faisalabad, and the PIDA. The project is working closely with farmer organisations in the command area of Lower Chenab Canal (LCC), which is located in the food bowl of Punjab.

Project leader Associate Professor Mohsin Hafeez, who heads CSU's International Centre of Water for Food Security, says researchers have assessed LCC system operations and are producing modelling tools capable of analysing hydrological and economic water management trade-off scenarios.

"The project team will use the results to develop conjunctive canal (surface) and groundwater management options which it will help to implement," Associate Professor Hafeez says. "The scientific insights of this project will empower PIDA and farmer organisations to manage and use water resources more rationally."

Associate Professor Hafeez anticipates the project will result in reallocation of more surface water to tail-end areas affected by saline groundwater. "There is huge potential to improve agricultural productivity and food security in Pakistan, with favourable economic, social and environmental impacts," he says.

"By coupling remote-sensing tools and hydrological data with socioeconomic data we will also be able to measure surface and groundwater supply and demand at various spatial scales to tailor adaptations to climate change, which could exacerbate the current situation."

ACIAR research program manager Dr Mirko Stauffacher says the project will drive greater adoption of on-farm water-saving technologies such as raised beds, drip irrigation, laser levelling and zero-till planting.

"It's about improving water-use efficiency and building capacity both upstream and downstream," Dr Stauffacher says. "The challenge is to find practices that are culturally, socially and economically acceptable."

– MELISSA BRANAGH-McCONACHY

PARTNER COUNTRY
Pakistan

PROJECT: LWR/2005/144: Optimising canal and groundwater management to assist water user associations in maximising crop production and managing salinisation

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PHOTO: YAHYA ABAWI

MODELS OF PREDICTION

Australian climate experts have developed models to predict seasonal water availability in Indonesia, helping farmers make more productive crop choices

BY CATHERINE NORWOOD

With little capacity to collect water for irrigation in either regional or on-farm storages, the many smallholder farmers on the Indonesian island of Lombok rely on rainfall to make their rivers run and provide water for their crops.

Australian scientists from the Queensland Centre for Climate Change Excellence (QCCCE) have been working with ACIAR and Indonesian Government agencies to develop climate and water-availability models for Lombok. The aim is to improve decision-making about irrigated cropping and increase profits for farmers, through a better understanding of long-term rainfall trends.

Project leader Dr Yahya Abawi, formerly with QCCCE and now with the Australian Bureau of Meteorology, says an analysis of past climate data shows that during La Niña weather patterns there is enough water to irrigate three crops in a year across most of the island—usually two rice crops followed by a break crop. Typically in a La Niña event, farmers can plant 100% of their land with the first rice crop, 80% with a second rice crop, and 50% of their land with a third crop.

"However, in an El Niño event, like the current one, there is likely to be water for only 95% of the first crop," Dr Abawi says. "And water availability will decline dramatically for further crops, particularly in the east, which is generally drier and more strongly affected by El Niño."

With a limited capacity to store water or regulate river flows, more accurate climate data are essential to helping the community plan for climate variability by providing more accurate seasonal outlooks.

The Australian team, through the ACIAR project, has developed the Flowcast model to analyse historical data and current weather conditions and provide forecasts of likely rainfall and stream flow to Indonesian agencies. The project has also trained staff at Indonesia's meteorological agency (Badan Meteorologi Klimatologi dan Geofisika) to use the model. The outputs from Flowcast are then used in an integrated quantity and quality model (IQQM) tailored to the Lombok irrigation system.

Staff at Indonesia's University of Mataram use information from the Flowcast and IQQM models for the CropOptimiser software, also developed as part of the ACIAR project. CropOptimiser analyses the complex climate, water and market factors to identify the most profitable alternative crops, given the likely water availability.

Farmers generally focus on rice crops for food security, which typically use 12–15 megalitres per hectare, although government regulations prevent them from growing three consecutive rice crops in order to provide a break for pest and disease control.

Dr Abawi says the aim is to identify those seasons when water availability is limited—and how limited it will be—to help farmers make choices about alternative crops that will use less water and will reach harvest. Soy and corn, using 4–5 ML/ha, are popular choices.

While some parts of the island have access to supplementary water for irrigation from community-owned embungs (small dams) or from groundwater, these sources are generally reserved for high-value cash crops such as tobacco, which are hand-watered.

Farms in Lombok average only 1,000 square metres, so the crop decisions of any individual farmer have a limited impact on water available to others, or on the oversupply of produce. However, recommendations about crop selection are often made at a subregional level by farmer cooperative committees. Recommendations at this level can significantly affect market supply.

These committees include representatives from government agencies, community elders, religious leaders and farmers. About 75% of farmers on Lombok have had no schooling and rely on the cooperatives for direction. Dr Abawi says the committees provide an important link between the science community, government agencies and farmers, and offer the best avenue of providing relevant information to growers.

While the three models—Flowcast, IQQM and CropOtimiser—each stand alone, together they provide a comprehensive planning toolkit in climate, water and agricultural management that can improve decision-making in Lombok. For the moment local expertise behind the use of the models is limited, but Dr Abawi hopes it will continue to grow with further training opportunities and as users become more familiar with the scientific approach.

He says one of the challenges has been to improve the links between different agencies, as well as to provide information for growers in a way that will be accepted in communities where traditional knowledge and beliefs are still the foundation for many farm decisions. Partnerships such as this between Australian and Indonesian scientists can positively influence traditional beliefs by presenting modern ideas in a practical context that farmers can apply and benefit from. ■

PARTNER COUNTRY
Indonesia

PROJECT: SMCN/2002/033: Seasonal climate forecasting for better irrigation system management in Lombok

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Equitable flows

Increasing urban and industrial demand for water in China is placing pressure on agriculture to use water more efficiently

BY WARREN PAGE

China's water use has risen to about 500,000 million litres, a five-fold increase over the past 60 years. Economic and population growth rates of about 7% and 0.5% respectively are the main drivers of increased demand. Underpinning this growth is a focus on exports and increased integration into the global economy.

One of the challenges presented is equitable distribution of water—between sectors, regions, industries engaged in export markets or domestic production, and within individual river basins and irrigation schemes. Water in northern China, where more grain is grown, is scarcer than in southern China.

The Yellow River Basin represents a convergence of many of these issues, with the river winding through a number of regions. More than 130 million people live in the basin and rely on water from the river system, many of them farmers relying on irrigation for their livelihood. Much of the irrigation infrastructure is of poor quality, with pollution also a growing problem.

An ACIAR-funded project examining water policies and institutions identified a range of impediments to effectively managing water resources. A major focus in the Yellow River Basin, and in many irrigation schemes, is on water-use efficiency and water-saving irrigation techniques.

Both approaches are effective in river basins and irrigation schemes that are yet to enter a 'mature phase' where all available water has been allocated, or in the case of the Yellow River Basin, over-allocated.

Government approaches to these water shortages utilise technical and engineering approaches, including emphasising water-

Irrigation is vital to ensuring cropping in parts of northern China.

saving technologies. Despite this investment, including in innovative delivery mechanisms, shortages continue.

In part these have been exacerbated by a lack of coordinated and integrated approaches between regions and sectors. Meeting demand in one sector or region can be achieved; however, too often this creates shortages downstream.

Another barrier is the lack of property rights to water, restricting the ability to price water through market interactions.

Irrigation schemes in China, such as the Zhanghe Irrigation Scheme, operate as centrally managed institutions, responsible for supplying water to end users. In the Zhanghe scheme, the subject of another ACIAR-funded project, improvements were sought for main system water management, where farmers are charged for any water they use.

Orders for water must be placed with the irrigation managers at the nearest canal station three days prior to delivery. The Main Canal office aggregates these demands to calculate the total inflow into the canal from the river system. Water is then priced on a volumetric basis—the more requested, the higher the bill.

The ACIAR project team, led by Professor Hector Malano of the University of Melbourne, found that the scheme operates as a disincentive to farmers to place advance orders. Instead the farmers delay orders in the hope of rain. Where rain does not fall, crops become water-stressed, resulting in a high number of orders, which then cause the system to become congested. The system is unable to meet this demand, resulting in only some orders being delivered.

Two computer-based models, developed through similar ACIAR-funded research into Vietnamese irrigation schemes, were adapted to the peculiarities of the Zhanghe scheme. The Irrigation Main System Operation (IMSOP) model was used to analyse and improve operations, with asset data collected and analysed by the ASSET Manager model.

Utilising the IMSOP model the project team was able to develop prediction and sequencing information, including linkages to climate data collected from a nearby weather station. More accurate management of demand in turn has helped make water-saving irrigation techniques more effective.

Changes to water pricing in the years prior to the project had exacerbated the farmers' habit of delaying orders, resulting in reduced demand and a revenue shortfall. This in turn impacted on the cost of water supply. The ASSET Manager model was used to calculate the actual operational costs and develop a sustainable fee structure.

Valuing water correctly is essential in any future approaches to water trading, including changes in the Yellow River Basin, as demonstrated by the ACIAR project. Property rights for water would allow farmers, villages and communities to buy and sell water, lessening the reliance on state-run irrigation systems to allocate water and set prices.

Similarly the lack of a value on water, other than in purchases from irrigation schemes, makes compensating for water transfers an impediment. This includes mechanisms to transfer revenues from water sales. Resistance to water-trading schemes has in part been based around uncertainties regarding water transfers on rural incomes, particularly where water is not priced and compensation not delivered.

Water trading may accelerate the adoption of local solutions to water scarcity by creating economic incentives for technical solutions based on local needs. Additionally, such approaches could also enhance grain self-sufficiency.

This could include adopting recommendations from the project to consider water use by crops. For example, the economics of transport and location suggest that high-value perishable crops be grown closer to urban centres, and crops that are more dependent on water, such as summer-grown cotton or maize, be grown in the wetter parts of China.

These and other key findings from research into institutional and policy arrangements relating to water in the Yellow River Basin have been used in AusAID project work on water governance in China, which has examined policies and priorities for institutional reform. ■

PARTNER COUNTRY

China

PROJECTS: LWR/2000/120: Institutions and policies for improving water allocation and management in the Yellow River Basin, China;
LWR/2001/001: Improving main system water management in China: a demonstration project in the Zhanghe Irrigation Scheme

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Irrigated water in China is often free, undermining efforts to ensure it is seen as a valuable commodity.

Less is more

The increased use of fertiliser has helped feed the world, but one ACIAR project is helping farmers on the North China Plain realise the impact of excess nitrogen on their finances, global warming and their most precious resource, water

BY KELLIE PENFOLD

Planting a crop may appear a simple proposition, but there are many elements that need to be balanced for a successful harvest. Whether on a large scale in the Australian wheatbelt or in a smallholding in a Chinese province, nitrogen (N) and water (H_2O) are two key elements that determine how the crop yields.

But when these elements are unbalanced it becomes more complex. Too much water and too much fertiliser—more than the plant consumes for growth—create a waste that can pollute waterways and generate greenhouse gases, particularly nitrous oxide (N_2O).

And although too much water hasn't been a great problem in Australia's dryland farming system in the past decade, Australian research into fertiliser efficiency is helping Chinese farmers achieve a better nutrient and water balance. Avoiding fertiliser waste means less water pollutants, lower farming costs and reduced greenhouse gas emissions.

ACIAR's work in improving water and nitrogen fertiliser management spans more than a decade of partnership.

Project leader Professor Deli Chen, from the University of Melbourne, the organisation commissioned to run the project, says the project's success has been in showing Chinese farmers that wheat and maize crops can be grown with lower fertiliser and irrigation applications, while retaining or increasing yield. In Australia the focus has been on demonstrating fertiliser efficiencies for reduced gaseous emissions, particularly of ammonia (NH_3), which is volatilised during urea fertiliser applications.

"An evaluation of farmers' economic and environmental perceptions found the objective of profit maximisation was the crucial factor in fertiliser decision-making in areas of China in which we worked," he says.

China is one of the biggest users of manufactured fertiliser, accounting for 30% of global fertiliser use. Dr Chen says recent estimates put China's annual nitrogen fertiliser consumption at more than 35 million tonnes, while the US uses about 19 million tonnes. China is also one of the biggest users of water for food production, using about 17% of the world's agricultural water.

As a result Chinese farmers are responsible for much of the hard-to-measure pollutants in the country's waterways and generate large amounts of the second greatest greenhouse gas contributor—N_2O—of which 80% comes from the soil, often as a result of fertiliser over-use or ineffective use.

Collaborating with ACIAR on the project were the Shanxi Academy of Agricultural Sciences, the Chinese Academy of Sciences, the Chinese Academy of Agricultural Sciences, the China Agricultural University and, in Australia, fertiliser company Incitec Pivot Ltd.

Three experimental Shanxi province sites growing wheat, cotton and maize were selected at Yuci in the Taiyuan Basin in the north, Yongji near the edge of the North China Plain in the south, and Hongtong which lies in between. An irrigated maize system in the western part of the Inner Mongolia Autonomous Region (IMAR), which was run in collaboration with an AusAID project (Alxa League Environmental Rehabilitation and Management), was used for data comparison.

Baseline research included farmer surveys and extensive soil tests and water measurements. A survey of 801 households in 10 townships in Yuci county showed high plant-available N and phosphorus (P) in soils due to excessive use of both nutrients, but severe deficiency in potassium (K), illustrating the need for balanced nutrient application.

While the project has been able to influence the decision-making of local farmers on fertiliser use, Dr Chen says education about efficient water use is a greater challenge. Irrigation water is unmetered in many of China's farming areas and the only cost to the user is the pumping. Dr Chen says China's goal of guaranteeing food supply, produced by low-income farmers, complicates the issue, as does a complex system of water institutions, policies and irrigation methods.

"I always ask educated officials what would happen if there was no metering or charging for electricity? You might think about using less, but only if you knew the benefits," he says.

By year two of the latest project the impact of excess irrigation was apparent. At the IMAR site it was found that 24–40% of irrigation water and 186–255 kilograms of N per hectare was leached below the root zone. It was estimated that 50–90% of applied N in irrigated maize crops in the region was being wasted.

PARTNER COUNTRY
China

PROJECT: LWR/2003/039: Improving the management of water and nitrogen fertiliser for agricultural profitability, water quality and reduced nitrous oxide emissions in China and Australia

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In 2008, three years of data from field trials at Yongji and Hongtong were collated to be taken to the wider farming community as part of the final year of extension in 2009. At Yongji, a 14% higher wheat yield was achieved with 18% less N fertiliser. Optimum applications of N based on a split application of urea were identified.

In Hongtong county, where traditionally farmers apply much higher fertiliser rates, the trials showed the targeted yield of 8.5–8.8 t/ha of wheat and 8.8–9.2 t/ha of maize could be achieved by using 47% less fertiliser for wheat and 61% less for maize, representing savings of up to $211/ha in a maize crop. The irrigation in the optimised treatment was also about 20 millimetres less.

"The benefits are not just financial," Dr Chen says. "That excess, unneeded nitrogen releases the N_2O gases back into the atmosphere, but for growers to understand the value they have to see savings for themselves. These people have little understanding of climate change and greenhouse emissions.

"However, by 2008 farmers near the experiment sites were applying N at the same rates as the optimised treatment."

Professor Xunhua Zheng, a researcher at the Institute of Atmospheric Physics at the Chinese Academy of Sciences (CAS) specialising in agricultural greenhouse gas emissions, used CAS funding to build automatic and continuous chamber systems to measure all three greenhouse gases at the Yongji site—N_2O, carbon dioxide (CO_2) and methane (CH_4) in the irrigated maize, wheat and cotton systems. Preliminary data from the first year of collection found sprinkler irrigation enhanced N_2O emissions compared with flood irrigation, and the less irrigation used the fewer emissions.

An internet-based, spatially referenced software system called a Water and Nitrogen Management Model (WNMM), developed in past ACIAR research and used in Australian agriculture, underpins the four years of research and extension work. A user-friendly and GIS-based decision-support system to deliver the most efficient nitrogen applications for irrigated crops was developed.

In the first year of the project WNMM was a focus for Australian researchers, with new modules added to simulate crop growth, pasture growth and the impact of grazing and N_2O emissions.

WNMM was then adopted by the Australian Cooperative Research Centre for Greenhouse Accounting for simulating water and N dynamics and N_2O emissions for rainfed wheat in Victoria and Western Australia and irrigated pastures in Victoria. These simulations were compared with N dynamics and ammonia (NH_3) volatisation in South Korea, water and N dynamics for an irrigated maize and wheat system in the Yaqui Valley, Mexico, and legume systems in China.

Dr Lin Yuntong and Dr Wan Yunfan with project leader Dr Deli Chen inspecting manual open-top chambers in a maize field.

"The benefits are not just financial ... for growers to understand the value they have to see savings for themselves." – PROFESSOR DELI CHEN

While the simulation found there was little difference in N_2O emissions in the rainfed cropping system in Australia with different stubble management techniques, it found the main driver for N_2O emissions is soil moisture rather than the availability of N, and when historic climate data was put into the system huge variations in N_2O emissions in the past 37 years were found. Emissions correlated with climate variables such as temperature and rainfall and the N fertiliser application rate. Dr Chen says the WNMM has been successfully applied to the irrigated pasture in Victoria, semi-arid wheat in WA and sugarcane in Queensland for simulation of N_2O emissions. The model can be used in a variety of farming systems across Australia to help manage emissions in the future.

"Capacity building has been important in this project and 12 young Chinese scientists have been trained to conduct complex laboratory and field experiments and surveys. Two WNMM modelling workshops have been held in Australia and one in China, training more than 30 people in the skills to use it. This is vital for good local research to continue," Dr Chen says. ■

WATER DEPTH THE ROOT OF THE PROBLEM

Indo–Australian collaboration is allowing plant researchers to attempt something that has defied breeders for years—adapting the root system of wheat to better perform in drought

BY DR GIO BRAIDOTTI

When it comes to breeding wheat better able to cope with water scarcity, there is one particular problem that has been taunting agricultural scientists for years—accessing deep soil moisture.

Just as crops are about to flower and set seed, residual water in the soil is frequently out of reach of the deepest roots of current wheat varieties. Breeders know that if they could change the 'architecture' of the roots they could make that water available … and, as a consequence, increase food production. Until recently the insurmountable problem was the technical complexity of screening and selecting for different kinds of root systems.

However, from 2009 an ACIAR-brokered project is allowing breeders from India and Australia to pool resources to crack the root problem. The scientists are sharing germplasm, field trials at four Australian and five Indian sites, and trait-selection technology in a bid to help dryland wheat farmers worldwide produce more grain from the same amount of water.

The project is the first undertaken as part of the Indo–Australian Program on Marker Assisted Wheat Breeding (IAP MAWB) with ACIAR and the Indian Council of Agricultural Research matching funding.

Pilot field studies have been underway in India since the 2008–09 growing season. Some key sites used in these studies are located in the central and peninsular states, where wheat is grown entirely on soil-stored moisture acquired during the monsoon; this makes them especially suited to root physiology work. With little rainfall to confound the study, the Indian team has near-ideal conditions to screen for variation in root architecture and evaluate its effects on yield.

Over the next four years, the Indian scientists from the Directorate of Wheat Research, the Indian Agricultural Research Institute and the Agharkar Research Institute will be working with Dr Richard Richards's CSIRO Plant Industry team in Canberra and Queensland, with Dr Michelle Watt serving as Australian project leader.

The CSIRO team ranks among the world's most successful at developing physiological tests that can detect—from among thousands of lines—plant attributes that can lift yields in dry conditions.

The team takes an idiosyncratic approach that avoids selecting for 'drought resistance', (Opposite page) Visiting a CSIRO field site to look at wheat establishment and root vigour are Dr Satish Misra (left) of the Agharkar Research Institute and Dr G.P. Singh (right) of the Indian Agricultural Research Institute. They were shown around by CSIRO's Michelle Watt (second from left) and Dr Richard Richards (second from right).

since resistance traits often allow wheat merely to survive drought. Instead CSIRO looks to improve 'water productivity', an approach developed by Dr John Passioura, CSIRO's renowned plant drought physiologist.

"One of the main factors limiting progress when it comes to breeding for dry conditions is inadequate 'phenotyping'—by which we mean the ability to characterise plant traits with the potential to improve water-limited yield," Dr Passioura says. "Almost all such phenotyping in the laboratory relies on screening plants for their ability to survive severe water stress, yet better survival rarely means better production."

By focusing instead on lifting production, over the years Dr Richards and his CSIRO colleagues have developed phenotyping technology that has resulted in the commercial release of new wheat varieties capable of remaining productive under a wide range of water-limited environments.

"The emphasis on water productivity is important because it opens three avenues for pre-breeders to identify better-performing wheat germplasm," Dr Richards says. "We can look for traits that improve the amount of water the crop captures, or the efficiency with which the crop uses the water, or the partitioning of growth into grain (the harvest index). If you can improve any one of those three then you will improve yield under drought."

To date, phenotyping technology developed at CSIRO Plant Industry has primarily targeted above-ground plant features. However, researchers know that root traits also stand to drive water-productivity gains, and the project finally shifts water productivity phenotyping research 'underground'.

Impressive gains are thought to be possible by selecting for deeper roots at around the time of flowering and seed-setting. Dr Watt says that any water taken up about this time is directly used for grain production. "We have calculated that the uptake of an extra 10 millimetres can contribute to an extra half a tonne of grain per hectare," she says. "So the deep-root trait has very high water productivity: a high conversion of water into yield."

Root length in mature plants, however, is extremely difficult to measure, especially when comparing water productivity in hundreds of wheat lines. It requires field plantings in real cropping zones and coring of the soil to a depth of two metres to physically measure the root system. Yet that is precisely what the Indian researchers are doing: coring at the ideal trial sites to find out how deep the roots penetrate in a wide range of elite wheat varieties, Indian

PARTNER COUNTRY
India
PROJECT: CIM/2006/071: Indo–Australian project on root and establishment traits for greater water-use efficiency in wheat
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'Stay Green' on the mark

By allowing breeding programs to bypass complex and time-consuming field trials at multiple sites and in different seasons, DNA markers are an attractive upcoming technology and ACIAR is promoting their development for traits that can help some of the world's poorest farmers.

Of particular interest is a trait that evolved in Africa that is likely to relate to an extremely efficient use of water, as well as differences in rooting. The trait was discovered in sorghum, a staple food for about 400 million people in 30 countries. Sorghum grain and straw (or stover) are also valuable as livestock feed in dry or marginal areas, such as parts of northern Australia and in the post-rainy season (Rabi) in India.

Dr Paul Fox, ACIAR's crop improvement and management research program manager, says that Ethiopian sorghum lines that can fill grains and mature even through terminal drought are of particular interest. The tolerance is due to a trait called 'Stay Green', in which a few leaves stay green long enough to provide the starch needed to fill grain.

"Stay Green was identified in several sorghum lines, including one called 'pineapple top', a low-yielding plant type that is not suited to commercial cultivation," Dr Fox says. "So we have a project to use the DNA markers of Stay Green and insert them into varieties that farmers are commonly growing. This will allow breeders all over the world to move Stay Green into more productive sorghum varieties."

The project is being undertaken in a partnership between India and Australia headed by Dr Vincent Vadez and Dr Tom Hash from the International Crops Research Institute for the Semi-Arid Tropics, in India. Participating from Australia are the University of Queensland and Queensland Primary Industries and Fisheries, which are working with India's National Research Centre for Sorghum and the International Livestock Research Institute.

Field activities started in India during the 2008–09 Rabi and will continue through to 2012, involving the Queensland researchers who are working on predicting the possible effects of Stay Green on yield across environments using crop simulation modelling.

The researchers know that Stay Green is a complex trait involving many genes, gene interactions and gene-by-environment effects. Cracking the molecular and physiological basis of a major drought-tolerance trait stands to deliver potentially enormous benefits in the long run, and not just for sorghum breeders.

"If we understand a drought-tolerant trait like Stay Green in sorghum, then the potential exists to use those genes and markers, and their related mechanisms, in other major food crops such as rice, wheat or maize, and that could have huge impacts on food security," Dr Fox says.

PHOTO: EVAN COLLIS

Dr Paul Fox, ACIAR's research program manager for crop improvement.

PARTNER COUNTRY
India
PROJECT: CIM/2007/120: Improving post-rainy sorghum varieties to meet growing grain and fodder demand in India
CONTACT: Dr Paul Fox, fox@aciar.gov.au

Dr Richard Richards

PHOTO: BRAD COLLIS

(From left) CSIRO's Dr Michelle Watt shows Dr Satish Misra and Dr G.P. Singh a screen for root vigour at a project workshop in Canberra, in September 2008.

"That's the great thing about the collaboration with India—there is a huge benefit from doing the work jointly."

– DR MICHELLE WATT

landraces and experimental CSIRO germplasm.

"A deep-root project on this scale has never before been attempted," Dr Watt says. "That is the great thing about this collaboration with India: they have the best field conditions to correlate root architecture and water productivity."

To make the most of the R&D opportunities, CSIRO intends to test the possibility of using simpler phenotypic tests to substitute for coring the soil. Under consideration is the use of thermal cameras to measure leaf temperature—a trait affected by the root's ability to make water available for transpiration by the leaves. Called 'surrogate traits', these substitution measurements offer immense benefits to breeding and research programs alike, but they first need to be rigorously validated under real field conditions.

"This ACIAR project can help validate the new technology because we are going to couple these measurements with direct coring and physical observation of the roots," Dr Watt says. "If these quick leaf measurements hold up in the field they could prove very useful for optimising water productivity and could become surrogate traits that are very attractive for use by breeders."

Besides deeper roots, CSIRO is also planning to test for a whole suite of other water-productivity traits, including a plant adaptation that can increase the amount of water that crops can capture. CSIRO has previously developed wheat lines that undergo very rapid early shoot growth, a trait that allows crops to establish quickly and which, by providing ground cover, minimises evaporation from exposed soil. This shoot trait helps to conserve soil moisture.

"At CSIRO we found that if we select for more vigorous early shoot growth we can also adapt varieties to perform better under conservation farming systems, where stubble from the previous crop is retained and the soil is not tilled to conserve soil moisture," Dr Watt says.

The CSIRO germplasm was developed as part of Dr Richards and Dr Greg Rebetzke's water productivity pre-breeding program and is being made available to the Indian collaborators for further field evaluation. Also making their way to India are wheat lines that use the *tin* (tiller inhibition) gene to reduce the production of kernel-bearing tillers (or stems). Dr Watt explains that the extra tillers tend to produce smaller kernels under dry conditions, and for Australian farmers this can incur a price penalty. The *tin* trait also offers a way to redirect the plant's energy away from tiller production and into root growth, allowing the plant to access extra water for grain production.

As each of these water-productivity traits are validated in the field over the next four years, new opportunities are being generated to benefit dryland wheat farmers, including stacking individual traits to consolidate breeding gains.

"That's the great thing about the collaboration with India—there is a huge benefit from doing the work jointly," Dr Watt says. "CSIRO has screening methods and is developing simple surrogate traits for complex developmental selections. India has the best field conditions to study root architecture and water productivity. And both countries hold some really interesting germplasm. Together we can realise the potential of these resources that ultimately provide a platform to identify important genes and develop molecular markers to make selective breeding far easier." ■

PHOTO: BRAD COLLIS

New rules for irrigation

By evaluating farmers' water scarcity in the context of the whole landscape, an ACIAR team is helping to develop new approaches to problems of sandy soils and low water availability in Vietnam's coastal farming regions

BY DR PETER SLAVICH*

Cashew farming offers promise to expand agricultural production and reduce poverty in one of Vietnam's poorest regions. Utilising wet season run-off for irrigation use in the dry season is vital to expanding this production, but requires some changes to how farmers approach water management.

Like most crops, cashews have stages of development that are sensitive to water stress, in particular those from flowering through to nut fill. On the southern central coast of Vietnam these stages coincide with the dry season, a coincidence that necessitates irrigation.

The region has up to eight months of dry season, which is also hot and humid. The coastal river flood plains are prone to flooding in the wet season and are mainly used for rice. The coastal zone and lower foothills of the river valleys are used for mixed farming, with both ground and surface-water resources for irrigation. Upland soils are subject to erosion in the wet season and many also have acidic subsoils. Farm incomes in the region are low and constrained by low soil fertility.

Farmers in the region currently use a rule-of-thumb approach to irrigation and there is a need for cost-effective tools to help them decide when and how much irrigation water to apply. This can vary widely with soil, crop and climatic conditions.

An ACIAR-funded project is currently evaluating mini-evaporation pans as an irrigation-management tool for tree crops in the southern central coast of Vietnam.

Taking part are Southern Cross University in Australia and the Vietnam Academy of Agricultural Science, together with the Vietnamese National Institute for Soils and Fertilizers and Department of Agricultural and Rural Development.

The mini-evaporation pan is installed in the farmer's field and observed daily. When evaporation causes the water in the pan to fall to a critical predetermined level, then it is time to irrigate. This level varies depending on the water storage capacity of the soil, the depth of the main root zone and the size of the tree canopy. The amount of irrigation water applied is also guided by these factors. The mini-evaporation pan is refilled at the start of each irrigation event and the process starts over.

> Farmers in the region currently use a rule-of-thumb approach to irrigation and there is a need for cost-effective tools to help them decide when and how much irrigation water to apply.

Results from field trials for the 2008–09 season indicate that cashew farmers who used the mini-evaporation pan irrigated every 4–5 days and applied about 500 litres of water per tree. This compares with 2,000 L per tree every 15 days under the rule-of-thumb approach.

Overall, irrigation based on the mini-evaporation pan resulted in reduced water use and higher yields. Evaluations of the mini-evaporation pan are continuing into the 2009–10 season, with an additional adjustment based on using the watertable depth as a trigger for commencing the irrigation season, as opposed to existing practice where many farmers currently use the end of the Tet holiday as a trigger to commence the irrigation season.

Work undertaken so far indicates that farmers will need to change their irrigation infrastructure if they are to use irrigation more effectively. This may be as simple as installing irrigation mains with several outlets or submains to transport water across their orchard. Alternately, investment in suitable pressurised drip or micro-sprinkler systems could be introduced if cost–benefit analysis indicates the expenditure is justified. ■

PARTNER COUNTRY
Vietnam

PROJECT: SMCN/2003/035: Improving the utilisation of water and soil resources for tree crop production in coastal areas of Vietnam and NSW

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** Australian project leader Dr Peter Slavich has more than 25 years' experience working in the areas of soil conservation and the management of production constraints such as acidic soils and salinity. He heads the Soil, Recycled Organics and Environmental Health research group at the NSW Department of Primary Industries (DPI) and serves as the Director of Wollongbar Agriculture Institute and the Centre for Coastal Agricultural Landscapes, an alliance between the NSW DPI and Southern Cross University, where Dr Slavich is an Adjunct Professor.*

GEOGRAPHY / CLIMATE

- Driest area of Vietnam
- Wet season 3–4 months duration
- Coastal, plains and mountainous regions
- Salinity present in coastal aquifers and soils

FARM

- 73% smaller than 2.45 ha
- Mixed enterprise – rice main crop
- Soils are sandy with acidic subsoils – lowering ability to hold moisture and nutrients
- Groundwater salinity common
- Water shortages in dry season common
- Labour in short suppy

PRACTICES – PRESENT

- 95% of farmers extract water from wells for irrigation
- Use of hand-held hoses or irrigated flooding at flowering
- Use of manure for soil improvements
- Use of inorganic/mineral fertilisers applied on experimental rules basis

CHANGES TO PRACTICES

- Time water applications using simple on-farm indicators
- Mini-evaporation pans used to indicate frequency of irrigation
- Use of bio-char from rice husks
- Apply fertiliser to bio-char
- Uses of standardised bunds

A farming snapshot – understanding the problem

ACIAR-funded project teams often work closely with farmers to establish new practices to boost agricultural productivity. A key component of this work is understanding the influences on farmers, from the climate and land they work with, through to constraints such as labour availability.

The project to improve water and soil resources for tree crop production surveyed 150 farms in Ninh Thuan and Binh Dinh provinces in 2007 to gain insight into farming practices used in the region, particularly for water and nutrient management. A follow-up with 15 farm case studies examined management practices, revealing a range of yield differences for cashew crops, from 04–2.5 t/ha, depending on variety, irrigation and nutrient inputs. Key findings are summarised in the diagram on this page.

Water and soil resources for tree crop production

Sandy soils (arenosols) occupy 900 million hectares, or 7% of the Earth's land area, and pose many constraints to agriculture, particularly when they occur where there are seasonal hot dry tropical climates.

Arenosols in the tropics usually have low water and nutrient-holding capacity due to their low organic matter content and clay contents. Carbon storage capacity—typically less than 0.5%—is limited by the low surface area available to bind with carbon compounds and low volume of small pores, which protect carbon from microbial activity.

This means farmers who are reliant on sandy soils need carefully designed and well-integrated water and nutrient-management systems to increase their productivity and reduce adverse effects on groundwater and soil acidity.

In the southern central coast region of Vietnam there are more than 500,000 ha of sandy soils that are derived from weathered granite, alluvial deposition and aeolian coastal sands.

TESTING THE WATERS

Despite significant government infrastructure investment, efforts to encourage smallholders in East Nusa Tenggara province to grow profitable vegetable crops have not been successful due to a series of contradictions that drive farmers' decision-making

BY WARREN PAGE

Villagers in Indonesia's East Nusa Tenggara province face high levels of poverty. Smallholders in villages such as Tupan, Manutapen and Oemasi grow maize as a staple crop, while also raising small numbers of cattle.

The Indonesian Government has been keen to help these farmers make the transition to growing vegetables to meet rising domestic demand and to help reduce poverty in the area. To do so the government developed water storages to equip smallholders with robust systems to help make the transition to vegetable farming.

Significant government investment centred around the construction of embungs—small water storages designed to capture sufficient water during the wet season to allow vegetable production in the dry season. Embungs are used for storing water for cattle and, in some cases, for human consumption.

The creation of the water storages should have resulted in more vegetables being grown but this was not the case.

An ACIAR-funded project focusing on the economic and social aspects of villagers' thinking was undertaken, with the aim of identifying the constraints to adopting vegetable production.

(Opposite page) Management of embungs is shared cooperatively by villagers.

The project conducted surveys and focus groups with farmers in Tupan, Manutapen and Oemasi villages, and immediately found a conundrum: 53% of these farmers said profit was the main reason for choosing a crop.

So why then is maize—a less profitable crop than vegetables—favoured over vegetables? And why has the construction of water storages, essential to production, not achieved the desired result?

The project team had a number of ideas for why this could be, including labour availability, capital and access to credit, market prices, risk, costs for maintenance of embungs, land and property rights, and limited knowledge of vegetable production.

Surveys and field interviews were used to test these ideas, ruling out some issues, while revealing a series of contradictions and conflicts that dent the confidence of farmers. Several issues were ruled out as constraints to changes in practice.

For example, labour is not seen as a major constraint, with an average of three out of five members of smallholder farming families available for work. In addition, these families did not rank labour availability as a problem that influenced decisions on growing vegetables.

Capital and access to credit were broad issues, particularly as more than 70% of farmers interviewed have no access to any type of credit facility and high levels of poverty make saving difficult. Despite this, 88% of survey and interview respondents are willing to contribute financially to maintaining embungs.

However, the survey team discovered that another factor, related to capital and credit, is more important. Most farmers have little ability to save and no access to credit, resulting in limited attention being paid to future planning, and making production and consumption for immediate needs the priority. This affects both capital accumulation and consumption patterns.

Another issue, identified by farmers as a major constraint, is lack of knowledge relating to vegetable production. In turn, this lack of knowledge affects the confidence of farmers, raising questions about pest and disease management, postharvest handling and basic production skills undermining their willingness to plan to grow vegetable crops.

This is compounded by a lack of understanding of markets and marketing, including logistical challenges relating to high transport costs, all of which extension services could answer. Yet only 5% of survey respondents had not met with extension services, and of those that did, 79% received training in water management and/or vegetable production.

The answer to this puzzle was revealed to be who was targeted by extension officers. Typically men were the group who met with extension services, but women are responsible for vegetable production and, to a lesser extent, water management. Extension services also focus on larger farms, where vegetable production is less profitable, rather than smallholders who stand to profit from changes in practice.

Water itself was cited by 74% of respondents as being available through embungs, yet lack of water for irrigation of vegetables is seen as a constraint. Much of this thinking relates to confusion over who owns embungs, and the water within.

Many embungs were built without sufficient consultation with village communities, creating a lack of clarity in terms of property and ownership rights, and who can use the water for what purposes. Most villagers see the embungs as the property of the government, rather than as communal property. This also impedes maintenance of embungs, which is needed to slow and then manage sediment build-up over time.

This mix of issues, plus the complex relations between them, has been revealed as the main barrier to increased vegetable production. Food security and traditional practices that create a bias towards certainty have undermined government efforts to create change. The knowledge from this project will be essential in addressing the social and economic issues, which have proven to be more important than water, in holding back farmers. ■

Typically men were the group who met with extension officers, but women are responsible for vegetable production and, to a lesser extent, water management.

PARTNER COUNTRY
Indonesia

PROJECT: SMAR/2007/219: Identifying economic and social constraints for water management in vegetable production in Nusa Tenggara Timur (East Nusa Tenggara) and Nusa Tenggara Barat (West Nusa Tenggara)

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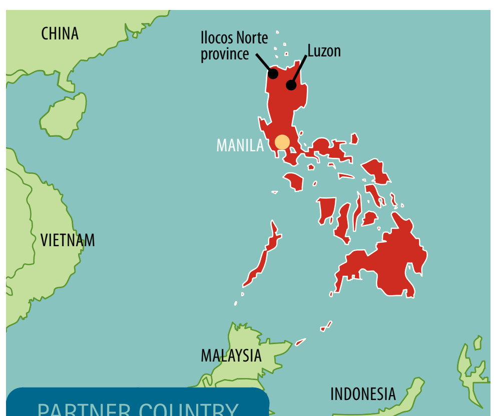
Sediment at the bottom of embungs is just one of a range of issues in water management.

Well-grounded water management


PHOTO: BRAD COLLS

Smallholder farmers in the Philippines are beginning to benefit from modern amenities but, as with many developments, this new opportunity also brings a challenge: to ensure sustainable management of water resources



PARTNER COUNTRY
The Philippines

PROJECT: SMCN/2003/035: Enhancing agricultural production in the Philippines by sustainable use of shallow groundwater

CONTACT: Dr Gamini Keerthisinghe, keerthisinghe@aciar.gov.au

BY WARREN PAGE

Smallholders farming in the northern Philippine island of Luzon do not rely entirely on rainfall as their only source of water. Pumping of water from underground aquifers is an important source, particularly for use in growing non-rice crops, such as mung bean, onion, garlic and other vegetables, in the dry season. These crops present the opportunity to help smallholder farmers earn new sources of income to escape poverty.

However, rising demand for these high-value crops has resulted in increased levels of groundwater extraction during the dry season. Extracting too much water becomes unsustainable, depleting the aquifer and altering the balance of these naturally occurring underground water storages.

Ilocos Norte province, on the north-western tip of Luzon, is one area where dry-season cropping is beginning to be practised. The province experiences two distinct seasons: wet from May to October and dry from November to April. The wet-season rainfall ensures lowland agricultural production and also recharges lowland aquifers.

Before vegetable cropping, rainfall had been sufficient to ensure that irrigation from pumped groundwater was needed only at the beginning of the dry season, to finish rice crops.

The main barrier to increased vegetable production has been the cost of pumping groundwater, as the diesel-fuelled pumps are expensive to run. Electricity is a cheaper source of power but has not been available in Pasuquin and Burgos municipalities, Ilocos Norte.

A new wind-turbine power station near Burgos is making electricity more widely available and reducing pumping costs. As a consequence newer, deeper-drilling pumps are becoming cheaper, threatening to significantly increase rates of water extraction.

The dangers of over-exploitation of groundwater include wells running dry, reduced crop yields or total failure, rising salinity and saline intrusion and, potentially, land subsidence. Finely balanced aquifers can reach levels of over-extraction quickly and once an overdraft of water occurs, a return to sustainable management is difficult.

Avoiding over-exploitation through management has been a goal of the Philippines Government and local authorities. However, their expertise was in the sand-based coastal aquifers common in the country, whereas the aquifer in Ilocos Norte is limestone.

ACIAR funded a project, partnering Australia's CSIRO Land and Water with the Philippines Bureau of Soils and Water Management, to develop planning and management options before groundwater depletion became unsustainable.

Without planning and management, poverty reduction and food security, respectively, would be threatened. While poverty may increase in the short term, as income from vegetable production is lost, food security could be compromised if in the long term groundwater became unavailable to finish rice crops and if wells providing household water ran dry.

The project team found some good news for smallholders: the combination of limestone aquifers and available run-off in the wet season suggested that a management plan for water recharge could protect the aquifer and still potentially support production even if a water overdraft were to occur.

To achieve this, a topographic survey was undertaken at project sites in Pasuquin and Burgos. The location of wells was mapped and combined with soil and land-use surveys and geological investigations to draw a complete picture of water use and aquifer health.

Watertable maps and salinity maps were then prepared, and water chemistry analysis undertaken. The survey of wells revealed 546 across the two project sites, with 355 wells used for household water and the remaining 191 used for irrigation.

Water in the aquifers fluctuated by as much as 3.5 metres at Pasuquin and 2.5 m at Burgos. Of total rainfall, about 10% of falls recharged Pasuquin's aquifers and 13–17% recharged the aquifers at Burgos.

Once a total picture of water resources was drawn, three groundwater models were used to forecast differing levels of sustainability. Four future scenarios were developed for each project site that modelled specific combinations of increased groundwater extraction, reduced recharge due to anticipated climate change impacts, and recharge augmentation. From the three models, one was chosen for each of the two project sites as the basis for economic modelling to demonstrate examples of increased or more efficient groundwater extraction and the resulting potential economic opportunities.

Without planning and management, poverty reduction and food security, respectively, would be threatened.

For example, in Pasuquin modelling of sustainable groundwater extraction demonstrates that about 90 hectares can be used for intensive garlic production in suitable areas in the dry season. This would involve relocating some production to more suitable soils, with a production increase of some 810 tonnes per year, representing an estimated 28.4 million Phillipine pesos in income.

The equivalent model for Burgos indicated that sustainable extraction was best in the mid-range of predictions relating to water usage, and could support some 60 hectares of intensive garlic production, yielding about 186 tonnes for a return of PHP11.1 million. Differences in production levels and returns are due to the soils in Burgos being only moderately suited to garlic production and evidence of increasing salinity during pumping.

Pumping of groundwater during the dry season must be done sustainably to ensure long-term use.

Limits to future groundwater extraction were projected. A crucial component of this management is educating farmers so that they recognise when overuse is occurring and have the ability to undertake immediate remediation practices. The project team focused on engaging farmers in planning and management, to ensure that the farmers themselves were able to become resource managers for the aquifers.

In June 2008, a farmer-managed groundwater system (FMGWS) in the project sites was implemented as a key component of the management strategy. This approach has been designed to increase farmers' awareness and understanding of groundwater and its occurrence, cropping pattern development and other technological concepts, leading to a more sustainable management of the groundwater resource.

An important element in management is reducing competition in groundwater extraction during the dry season. A coordinated pumping schedule could significantly reduce pressures on the aquifers.

Training modules suited to the needs of smallholder farmers, including elements unique to the Philippine setting and culture were prepared.

With these modules, several other sub-modules expressed in local dialect were developed. From January to June 2009 FWS classes were conducted at both project sites.

The result of this engagement with farmers has been a Covenant of Support to protect and manage the shallow groundwater resource. This covenant was presented to local policymakers who showed their willingness to provide a parallel effort to protect and manage the shallow groundwater resource by espousing related local policies. Furthermore, it was agreed that this should be referred to the National Water Resources Board, the agency that regulates the utilisation, protection and management of Philippine water resources. ■

Fish from the main flow of the Mekong provide a significant food source for half the population of Laos.

PHOTO: BRAD COLLIS

FISHWAYS BREAK DOWN THE BARRIERS

Fish in the Mekong River provide food security for millions of people. However, thousands of weirs on the river's tributaries and flood plains are preventing fish from reaching vital breeding grounds. Fish passageways may hold part of the answer to the problem

BY MANDY GYLES

The Mekong River, and its highly productive flood plains, flows life through Lao PDR, providing water for irrigation, transport and replenishment of soil nutrients, and its fish sustain the livelihoods of millions of people.

The Mekong supports the world's largest inland fishery, with an annual harvest of 2.2 million tonnes, equivalent to 2% of the total global catch. In Laos alone, most of the country's six million people fish, mainly in the Mekong and its tributaries, and fish are by far the most important source of animal protein and calcium.

However, thousands of weirs on the flood plains are preventing the movement of migratory fish between the rivers and their breeding and nursery habitats. While necessary for other aspects of life in Laos, the barriers result in reduced fish yields because the highly productive wetland habitats are not available to the fish. An ACIAR fisheries project may now provide a solution to this dilemma.

ALLOWING FISH MIGRATION

In many areas of the world fish-passage facilities, such as fishways or fish ladders, maintain pathways past artificial barriers for migratory fish in order to prevent population decline. However, to date, fish-passage management guidelines have been poorly defined in Laos and other Lower Mekong countries.

In Pak Peung village, in Bolikhamxay province, the success of an ACIAR-funded fishway pilot project suggests that constructing vertical slot fishways could provide a useful management tool for rehabilitating floodplain wetland fisheries in central Laos.

Fishways allow fish to pass around a barrier by swimming through a series of gaps or slots that control the speed of water flow. The experimental vertical slot fishway installed at a floodplain regulator in Pak San allowed more than 2,000 fish from 50 species to successfully gain passage in the first two weeks of the experiment.

The Lao director of capture fisheries, Douangkham Singhanouvong, says the project team is focusing on small-scale weirs, less than about six metres high. "In the future, we will encourage engineers to include fishways in the design of all new weirs."

AUSTRALIAN TECHNOLOGY

The Australian project leader, Dr Lee Baumgartner, a freshwater fish ecologist based at Industry and Investment NSW's Narrandera Fisheries Centre, has been working on the A$150,000 project with scientists from Laos's Living Aquatic Resources Research Center, the National University of Laos, and Queensland Primary Industries and Fisheries.

"Fishways have been widely constructed in Australia and are very effective at facilitating migration of native fish past weirs. However, in Laos there are no functional fishways," Dr Baumgartner says.

He concedes that the few fishways that have been built in the Mekong have performed poorly because they were based on fishway designs that did not consider the behaviour and swimming ability of local fish species.

"Each weir on a river that is targeted for fishway construction is unique. Fishways need to be designed to cater for the physical characteristics and swimming abilities of the local fish community. Typically, smaller species of fish are weaker swimmers and are unable to negotiate faster flows. The hydraulic conditions within a fishway therefore need to provide both enough depth for large fish while ensuring the velocity is suitable for smaller fish," he says.

During the recently completed ACIAR project, the scientists installed an experimental fishway on a known migration barrier and used it to determine the maximum swimming speed of the fish in the Mekong River. They are now installing a permanent fishway structure based on the experimental outcomes.

"So our first step with fishways has been to develop appropriate design criteria and demonstrate their effectiveness for fish in the Mekong Basin," Dr Baumgartner says.

"With increased understanding of local fish species' swimming ability and behaviour, local design criteria can be applied and adjusted so that successful fishways can be built. However, the higher the passage, the greater the challenge and our work is generally applicable for barriers less than six metres in height."

Dr Baumgartner says the research has application in Australia. "Although most Australian fishways are successful for large fish species, scientists have had significant trouble assisting the migrations of very small fish species. Small species are abundant in the Mekong River, so we hope information generated from the research will allow the construction of more efficient fishways in Australia."

Fishways control the speed at which water flows, allowing fish to pass around weirs.

PARTNER COUNTRIES
Laos, Thailand

PROJECT: FIS/2006/183: Development of fish-passage criteria for floodplain species of central Laos

CONTACT: Dr Chris Barlow, barlow@aciar.gov.au

THAI INVOLVEMENT

The Thailand Department of Fisheries has also gained much recent experience with fish-passage technology through previous biological assessments undertaken at Pak Mun and trap and transport fishways at other sites of key significance in the Mekong Basin.

Hydropower dams and fish in the Mekong

ACIAR's fisheries research program manager Dr Chris Barlow was previously chief technical adviser for fisheries at the Mekong River Commission, based in Vientiane, Laos, for nine years. He stressed that fishways are not the solution for the problem posed by large dams.

Dr Barlow said fish passageways can be used to help fish migrate upstream around low barriers like weirs, but they are not a realistic solution for overcoming the barriers posed by large dams like those being built for hydro-electricity.

Thai fisheries researchers are collaborating with Lao and Australian scientists to value-add to the existing assessment of fish passage in Laos. These collaborative efforts will be used to consolidate existing work in the wider Mekong regions and to develop a plan to improve opportunities for fish passage at the estimated 10,000 low-level barriers to fish passage in Thailand and Laos, and farther downstream in Cambodia and Vietnam. ■

More frequent and severe droughts are regarded as the single biggest threat to the world's supply of arable farmland.

PHOTO: EVAN COLLIS

Scientists rally to the challenge of a DRYING PLANET

The world's leading drought specialists gathered in Shanghai recently to advance global research into more water-efficient and drought-tolerant crops

BY DR GIO BRAIDOTTI

There is a consensus among agricultural scientists that water scarcity is currently the most persistent reason for rural poverty and the single greatest factor determining crop yields.

Adding to that strain, agricultural scientists are faced with the need to double crop production by 2050 using current water availability. As part of the global effort to meet the challenges posed by water scarcity, scientists from around the world met in Shanghai for the Interdrought-III conference to step up drought-related research efforts in agronomy, plant breeding, genomics, transgenics and water management.

Six hundred agricultural scientists at the conference, including Australian researchers and their collaborators involved in ACIAR-funded projects, rated drought as the biggest threat to food production in developing and developed countries. The conference was hosted by the Shanghai Academy of Agricultural Sciences and the Shanghai AgroBiological Gene Centre.

The purpose of the meeting, said one of the fathers of drought-stressed-plant physiology, Israel's Dr Abraham Blum, was to respond to the plight and the need of farmers all over the world, including poor smallholders, whose livelihoods are constantly threatened.

One of the most significant responses to the many challenges posed by water stress has occurred in China. Dr Blum said China was defying trends in the developed world by massively boosting spending on agricultural R&D.

A dozen presentations by Chinese researchers demonstrated the breadth of the drought work being undertaken. Government start-up projects there are linking scientists with farmers to create a "second Green Revolution" based on more efficient and ecologically sound uses of water resources in conjunction with water-efficient farming systems and crop varieties.

Dr Peng Shigi from the Chinese Ministry of Agriculture provided a snapshot of the state of China's water resources. She explained that the development of irrigated agriculture had played an important role in China's agricultural development (only 30% of grain is produced by dryland farming). Today, 70% of China's total annual water supply is used in irrigation.

However, with urbanisation and rising living standards the amount of water needed for domestic and industrial use is on the rise, straining the nation's already overdrawn resources. More frequent drought events are further adding strain and rendering once-arable land desert. The ministry estimates that if left unchecked, the effects of pollution, climate change and land degradation will make drought events more frequent and catastrophic.

"Agricultural production suffers the threat of severe drought," Dr Peng said. "The direct reduction of grain output has (already) reached 20 million tonnes a year. Water savings and raising the efficiency of water use in agriculture is an important guarantee for agricultural development in the future."

Dr Zhang Qifa from Huazhong Agricultural University explained that past agricultural practices emphasised yield above all other considerations and led to the unsustainable use of nitrogen and phosphorus fertilisers and the indiscriminate use of pesticides, which added water-quality issues to overstrained water supplies.

"The Government is now calling for a second Green Revolution based around more sustainable farming practices, with Chinese scientists mandated to increase production while using less inputs and making more efficient use of water," Dr Zhang said.

Chinese agricultural scientists are targeting opportunities provided by both agronomy and plant breeding for water savings and efficiencies. Molecular breeding technology in particular is being scaled up and includes GM technology to test and deploy genes associated with 'drought tolerance' traits. These efforts are targeting both irrigated and dryland areas.

On the land management front, Dr Peng described three core strategies:

- Improve dryland production, especially by applying conservation farming techniques, recycling field run-off and making more water-efficient crops available—a strategy currently seeing sorghum heavily promoted to farmers by the Chinese Ministry of Agriculture.
- Limit the amount of water used in irrigated fields in ways that maximise yields. This approach is seeing drip irrigation, deficit irrigation (DI) and partial root drying (PRD) optimised for use in grain and horticultural production systems across China.
- Consideration for the needs of natural systems where competition between agriculture and natural ecosystems is leading to encroaching desertification.

Australia is already well advanced in many of these techniques and, through ACIAR, is helping their wider adoption in developing countries where there is growing momentum to adopt water-conserving farming techniques. Collaborative research projects are helping to adapt existing techniques such as zero-tillage and stubble retention, drip irrigation, DI and PRD for use in China, India, Bangladesh, Syria and Iraq.

On the breeding front there are major pushes to identify plant traits that improve water-use efficiency (WUE), especially in cereals.

Promising levels of genetic gain have been achieved, especially in maize, rice, pearl millet and wheat, with researchers from the centres of the Consultative Group on International Agricultural Research (CGIAR) playing leading roles. Once again, Australia is involved in a number of ways: through funds provided by ACIAR to the centres, through the involvement of Australian scientists, and in collaborative R&D projects.

CGIAR's International Maize and Wheat Improvement Center (CIMMYT) has achieved impressive results in maize using a selection technique called managed stress screening (MSS). The project, which has been running for 12 years, targets farmers in Africa and is headed by Dr Gary Atlin and Dr Marianne Bänziger.

The value of CIMMYT's protocol was formally tested in 2001–02 when its MSS-selected varieties were compared with those produced by other seed producers, including Monsanto.

"These were large experiments and the CIMMYT maize showed a 12–18% yield advantage over other varieties when tested in low-yielding environments," Dr Atlin said. "The yield differences were smaller but persisted in higher-yielding conditions. It seems unlikely that molecular markers or transgenics delivered the same gains for the time and money invested. So this breeding protocol works very well."

An agreement is now in place that will see CIMMYT's maize germplasm combined with Monsanto's drought-tolerance gene technology and field tested in Africa. The deal will see technology fees on any resulting varieties waived for African farmers.

Furthermore, the protocol has been adopted by the CGIAR's International Rice Research Institute (IRRI) to develop drought-tolerant rice varieties using field sites where water stress can be managed by draining and irrigating as needed. About 900 rice lines have been tested and IRRI has identified germplasm that yields 50–100% higher under drought stress.

"The CIMMYT and IRRI breeding programs have demonstrated that gains in drought tolerance from MSS are subsequently expressed in the target farming environment," Dr Atlin said. "Generally, MSS in maize and rice has proven adequately repeatable as a breeding strategy on a single-site basis."

Molecular breeding technology is also being applied. For drought, this primarily involves mapping regions of the genome associated with improved WUE, followed by either the development of molecular markers to facilitate selective breeding or gene discovery to develop GM varieties.

At Huazhong Agricultural University, Dr Zhang's team is using two genes identified by IRRI to change the performance of Chinese rice to common water stresses. These are the *Sub1* gene, which provides rice plants with tolerance to submergence underwater during flooding, and the *Saltol* gene, which provides a measure of tolerance to saline water. Projects are also underway to locate genes associated with drought tolerance and a dozen such genes are currently undergoing testing in an extensive transgenic program.

At the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), impressive gains have been made using the most drought-tolerant cereal crop—pearl millet—in collaboration with India's Central Soil Salinity Research Institute, the All India Coordinated Pearl Millet Improvement Project and the Institute of Biological, Environmental and Rural Sciences in the UK.

Pearl millet is the staple cereal and fodder crop grown in the hottest, driest regions of Sub-Saharan Africa and the Indian subcontinent, but Dr Rattan Yadav said that post-flowering drought stress consistently and drastically reduces yields and yield stability. However, a single discrete site in the pearl millet genome has now been identified that can account for 32% of yield variation seen between varieties during terminal drought.

"This site is associated with maintaining yield, biomass and harvest index under drought and in delaying leaf rolling," Dr Yadav said. "It also provides an added advantage under salt stress."

Similar mapping approaches are underway in wheat, durum, barley, sorghum, peanuts, cotton, chickpeas and common bean. Australia is involved in some of these efforts, with projects at the Australian Centre for Plant Functional Genomics, CSIRO Plant Industry and Queensland Primary Industries and Fisheries.

Most of the advances have come from measuring root and leaf characteristics long known to be associated with drought tolerance, Dr Blum said. However, he added that relatively few new drought-tolerance traits have been identified since the 1970s. The most valuable is carbon isotope discrimination—a technique developed in Australia and used by Dr Richard Richards and Dr Greg Rebetzke's CSIRO Plant Industry teams to develop more water-efficient wheat varieties.

Addressing delegates in Shanghai, Dr Rebetzke presented the next generation of wheat WUE traits under development at CSIRO. These include early shoot vigour, reduced tiller numbers, and the replacement of dwarfing genes that are more compatible with WUE.

"We sought an alternative dwarfing gene and found one (*Rht*) that reduces height without reducing seedling growth," Dr Rebetzke said. In adapted backgrounds, the early vigour trait is now associating with yield increases of 7–16%, reaching as high as 38% under some circumstances."

The Shanghai conference was the third time in 12 years that scientists have met under the Interdrought banner, with prior meetings in Montpellier, France, in 2001 and Rome in 2005. Because of the growing urgency surrounding drought and a drying climate, the period between conferences is being reduced to three years, with Interdrought-IV scheduled for Perth in 2012. ■

Six hundred agricultural scientists at the conference rated drought as the biggest threat to food production in developing and developed countries.

NEW ACIAR PROGRAM STRUCTURES

ACIAR has made a change to its organisational structure following the departure of Dr John Skerritt, who was deputy CEO and responsible for Research Programs.

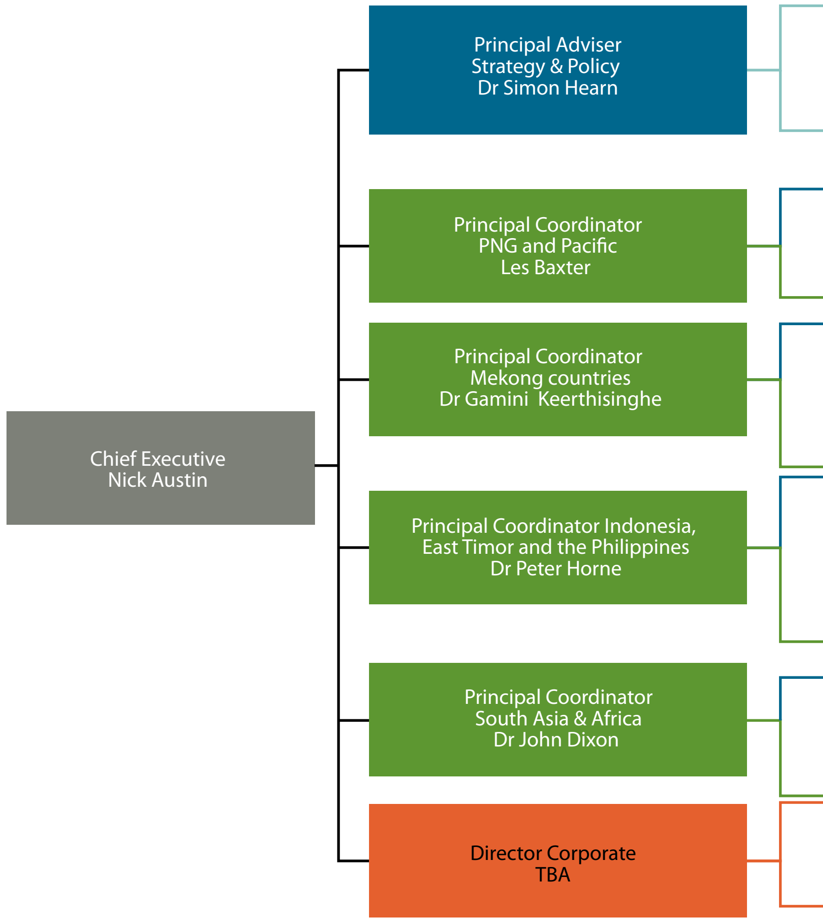
The Research Programs area now has principal regional coordinators (PRCs) responsible for overseeing ACIAR research activities across four regions. The PRCs, by region, are:

- PRC PNG and Pacific – Les Baxter
- PRC Mekong and China – Dr Gamini Keerthisinghe
- PRC Indonesia, East Timor and the Philippines – Dr Peter Horne
- PRC South Asia and Africa – Dr John Dixon

The key duties of the new PRCs will be:

- strategic planning and budgeting;
- project development, reporting and review;
- stakeholder liaison;
- country manager relationships; and
- research program manager relationships.

In addition, Dr Simon Hearn will take up the role of principal adviser for strategy and policy.



Deputy CEO moves to greener pastures

Dr John Skerritt left ACIAR late last year following his appointment as deputy secretary of the Victorian Department of Primary Industries (DPI). In his new role, based in Melbourne, John is responsible for overseeing four divisions of the Victorian DPI, with about 1,200 staff at several dozen locations, covering the state's agriculture, fisheries, forestry (on private land), biosecurity and emergency planning activities.

John's contribution to ACIAR spanned more than a decade. He was responsible for both the strategic direction and delivery of ACIAR's research and development program and played a leadership role in negotiating, designing and establishing project partnerships valued at more than $500 million in that time. During his decade with ACIAR, John played a key role in leading changes to the structure and function of ACIAR's programs, including recruiting the current cohort of research program managers. He established planning and reporting approaches on a country basis; fostered country and regional teams under the leadership of regional coordinators; initiated new R&D programs and positions in agribusiness, agricultural systems, agricultural policy, horticulture and soil management, and crop nutrition; and developed offshore research management positions to strengthen our local presence and program-management capabilities.

Under John's tenure the project partnership with AusAID expanded from $1.5 million of co-funding annually to almost $20 million this year, and he fostered major new collaborations with the World Bank, the Asian Development Bank (ADB) and the International Fund for Agricultural Development (IFAD), as well as non-government organisations such as World Vision and a range of commercial partners. The postgraduate (John Allwright) program increased eight-fold in size under his stewardship and John led the development of new research management training programs for mid-career professionals.

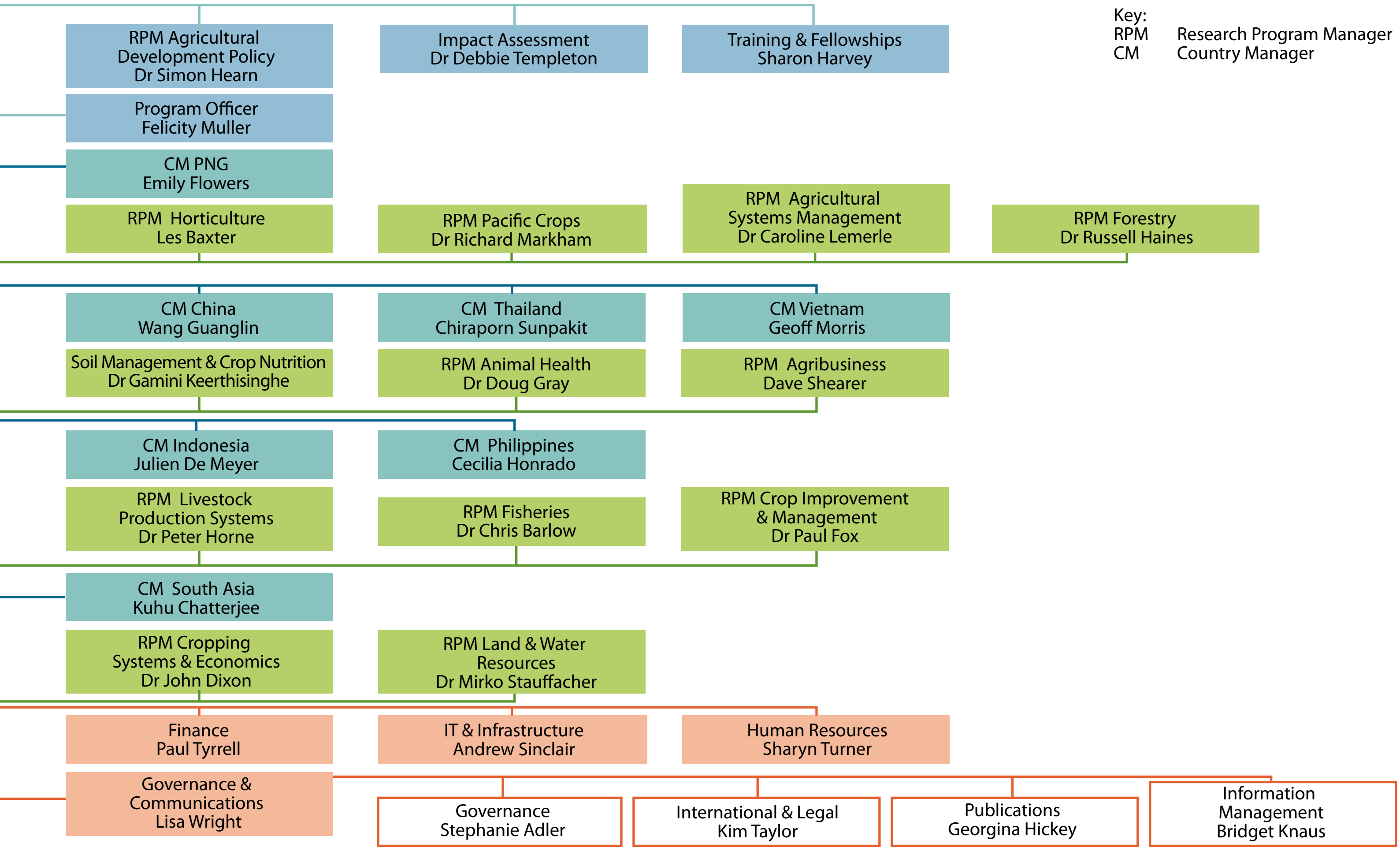
Members of the then ACIAR Board of Management, including Dr John Skerritt (centre) during a field visit.

Crawford Fund Conference 2009

With the increased prominence of food security and the rise of public sector investment in aid, including agricultural R&D, what is the place of the private sector? Last year's conference of the Crawford Fund,

round up

news and events from around aciar



held at Parliament House, Canberra, addressed the question: 'Can Private Sector R&D Feed the Poor?'

The world food price crisis of 2008 activated much-needed international and Australian attention, action and funding to improve world food security. Some of the best thinkers on the intersecting roles of the private, not-for-profit and public sectors in global food security addressed the conference on these pressing issues, providing a platform to guide corporate and public decision-making.

Australia's Minister for Foreign Affairs Stephen Smith, the executive director of the Syngenta Foundation for Sustainable Agriculture Dr Marco Ferroni and Professor Philip Pardey, professor of science and technology policy at the University of Minnesota, were keynote speakers.

Minister Smith revealed his deep concern for the world's poor in his address, observing that the food security crisis of 2008 had brought into stark relief not only the fragile state of global food security but also the global decline in focus and effort in agriculture and agricultural research. Internationally, Australian agricultural research is held in high regard—thanks to the work of organisations such as the Crawford Fund, ACIAR and AusAID. He said the Australian Government had stepped up support for a greater research effort and also increased its contribution to the United Nations World Food Programme.

A number of speakers with connections to ACIAR also addressed some of the potential roles of the private sector. ACIAR program manager Dr Doug Gray spoke of the contribution of livestock to food security and poverty alleviation. He noted that lack of incentives for cooperation between the public and private sectors had led to the neglect of important livestock diseases, some of which can also infect humans. A better public–private sector alliance was needed to develop new products including vaccines, drugs and diagnostics. Enhancing access of poor farmers to markets can also open new pathways for research to deliver benefits.

Long-time ACIAR project leader Dr Jeff Tullberg addressed the problems and potential of agricultural machinery. He noted that although national governments and aid programs have attempted to accelerate the mechanisation process in

Increasing the production of more specialised commodities suited to commercialised food production systems, can reduce poverty.

ACIAR's Policy Advisory Council met between 16 and 21 November 2009, to discuss research priorities with a range of Australian stakeholders, including the Minister for Foreign Affairs, Stephen Smith. As part of the meeting members of the council toured parts of Queensland where different agricultural enterprises are practised, and met with researchers and scientists from a range of institutions and departments. The council also met with the ACIAR Commission in a joint meeting, with topics discussed including food security and a meta analysis of climate change and how ACIAR research can help in areas of mitigation and adaptation. International members of the Council are shown above during their visit to Parliament House, Canberra. Pictured from left to right are: Mr Jia Jingdun, China; Dr Monthathip Chanphengxay, Lao PDR; Dr Mangala Rai, India; Dr Nguyen Van Bo, Vietnam; Dr Muhammad Tusneem, Pakistan; Dr Men Sarom, Cambodia; Dr Leah Buendia, Philippines; Mr Brown Bai, Papua New Guinea, and Mr Peter Forau, Fiji.

developing nations, the results have been generally disappointing. However, successful examples were emerging from some work funded by ACIAR and the International Rice Research Institute (IRRI). Parts of China, Vietnam and India had introduced mechanisation into their conservation agriculture. In addition, significant local commercial engagement had been important in the adoption of conservation agriculture in South America.

Dr Peter Horne, ACIAR program manager for livestock production, focused on how increasing urbanisation and the globalisation of food production were creating new opportunities for smallholder farmers in Asia. He said this was enabling them to move from subsistence agriculture to producing more specialised commodities suited to commercialised food-production systems. He observed that in most countries government extension services had been unable to engage effectively with commercial supply chains, but increasingly the private sector is investing in agricultural research, with great potential to benefit smallholder producers.

At the conference dinner the Parliamentary Secretary for International Development Assistance, Bob McMullan, gave the Sir John Crawford Memorial Address. He described Sir John as one who envisioned Australia as a source of principle and fairness in building new institutions for a global world. "Eschewing the old paternalism, he helped to hammer out the new global model of aid based on the concept of 'partners for development', in which countries work side-by-side to solve development problems," Mr McMullan said.

He lamented that agriculture's share of overseas aid had declined, globally, from more than 17 per cent in 1980 to just 3.8 per cent or less today. But he emphasised that Australia was playing its part to reverse this situation.

"Many of these investments needed to advance agriculture can only be made in the public sector. However, they alone will not solve the problem. There needs to be equally extensive investment by the private sector, including by millions of farmers and their suppliers around the world. But the private sector will not invest unless it is profitable to do so," Mr McMullan asserted.

Agriculture institute marks 10-year anniversary

The National Agriculture and Forestry Research Institute (NAFRI) of the Lao PDR, based in Vientiane, celebrated its 10th birthday on 3 January 2010.

In the past 10 years, NAFRI has successfully researched and improved crop varieties, tree seeds and livestock-rearing techniques to help farmers boost yields and improve their living conditions, said the Director-General, Dr Bounthong Bouahom, in a speech to mark the anniversary.

He said the institute had strived to develop the agriculture and forestry sector, improve food security, and enhance sustainable resource management and land allocation.

The institute had successfully surveyed and chosen 28 species of trees for plantation in 17 provinces, and established teak and agarwood protection areas in Xayaboury province.

More than 10,000 types of rice seed have also been added to the store of 2,000 rice species in existence 10 years ago. The types of rice seed now grown in Laos number 15,800.

Seed selection by the institute using new techniques has also enhanced 10 rice types most suited to conditions in Laos which can increase yields each year and provide sufficient rice for domestic consumption.

Commercial rice production for export has also expanded, especially using the khao kaynoi and homsangthong rice types, Dr Bounthong noted.

"We have gathered samples of more than 2,000 species of vegetables at our institute and preserved 90 kinds of sweetcorn, and also surveyed fish movements in the Mekong River, particularly the more than 100 species of fish that inhabit southern Laos," Dr Bounthong said.

The institute has studied 500 fish species in total, of which 30 types are suited to domestic breeding in ponds and natural streams, he said.

Such research has directly benefited the livestock and fisheries sector, resulting in increased food production, especially protein, for domestic consumption.

Dr Bounthong explained that in agriculture, the agroecology system uses new technology to compensate for traditional methods as part of necessary steps to increase commercial crop production to meet present demand, while keeping producers' costs low.

The system also protects against the soil erosion and reduction in soil quality that can result from the cultivation of cash crops such as sweetcorn, cassava and soybeans, he said.

The institute works in cooperation with local technical staff and partner farmers, who also benefit from new techniques by breeding animals through artificial insemination, improving animal feeds, organic planting of vegetables out of season and short-term crops, and industrial trees.

Each year these techniques have developed and expanded to more farmers throughout the country, to help reduce poverty in line with national socioeconomic development goals, Dr Bounthong said.

NAFRI has been a project partner in a number of ACIAR-funded projects including in the areas of development policy, forestry, animal health and cropping systems.

More information: www.nafri.org.la

Helping to develop evaluation champions

A workshop on social science concepts and tools for technology evaluation and impact assessments held in the Philippines contributed to creating an impact/evaluation culture in a wide range of agricultural research institutions.

Eighteen collaborators from 10 countries—Bangladesh, China, India, Indonesia, Laos, Burma, Pakistan, the Philippines, Nepal and Vietnam—took part in the two-week workshop, including 11 people working on ACIAR-funded projects.

The workshop was coordinated by Dr Sushil Pandey and Ludy Velasco of the International Rice Research Institute (IRRI), with ACIAR's impact assessment program manager Dr Debbie Templeton.

Participants gained the knowledge and skills to enable them to undertake social and economic evaluations of prospective technologies and to assess the economic impact of completed agricultural research projects.

They took part in hands-on exercises to help them apply the concepts and use the tools in conducting impact assessments in their home institutions. Meeting with farmers and other locals from Tubuan village in Pila, Laguna, and conducting focus group discussions, also gave participants an understanding of local concerns and the similarities with farmers' concerns in their respective countries.

Dr Templeton said the workshop set out to develop an impact/evaluation culture within the individuals who took part, so they could be evaluation 'champions' in their institutions.

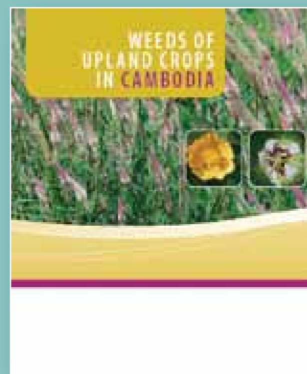
ACIAR has a long history of assessing the impact of its research and development investments. The assessments provide valuable lessons for improving the selection, design and delivery of projects, as well as demonstrating the value of ACIAR as part of Australia's international development assistance program.

More information: ACIAR's impact assessment program, www.aciar.gov.au/measuring_impact

NEW PUBLICATIONS

MONOGRAPHS

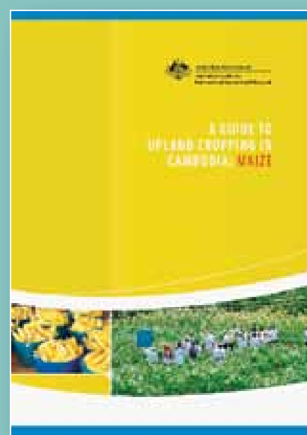
Weeds of upland crops in Cambodia



A weed-identification guide for farmers and extension workers in the upland cropping systems of Cambodia. Sponsored by ACIAR, the NSW Department of Primary Industries and the Cambodian Agricultural Research and Development Institute, this book is part of a series of publications produced by ACIAR in support of the ongoing rollout of on-farm demonstrations for upland crops in Cambodia.

Robert Martin and Pol Chanthy, ACIAR Monograph 141, 82pp.

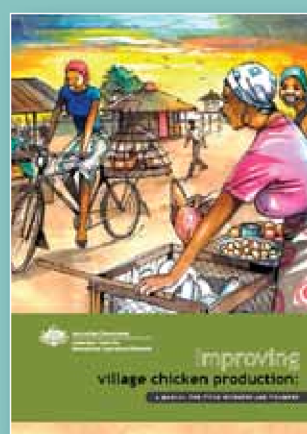
A guide to upland cropping in Cambodia: maize



In response to the Royal Cambodian Government's National Poverty Reduction Strategy (2003–05), ACIAR funded research to develop sustainable farming systems for crops. The aim was to help reduce poverty and contribute to food security at household and national levels through the development of technologies and opportunities for the production of non-rice upland crops. This book is part of a series of publications produced by ACIAR in support of the ongoing rollout of on-farm demonstrations for upland crops in Cambodia.

S. Belfield and C. Brown, ACIAR Monograph 140, 44pp.

Improving village chicken production: a manual for field workers and trainers



Australia has supported the implementation of effective village chicken production programs in Asia, Africa and Latin America, including several research projects funded by ACIAR. This investment in R&D, always in collaboration with producers, traders and other stakeholders, has been shown to increase poultry numbers, household purchasing power, home consumption of chicken products (resulting in improved nutrition for families) and the decision-making power of women. This manual focuses on developing countries.

C. Ahlers, R.G. Alders, B. Bagnol, A.B. Cambaza, M. Harun, R. Mgomezulu, H. Msami, B. Pym, P. Wegener, E. Wethli and M. Young, ACIAR Monograph 139, 194pp.

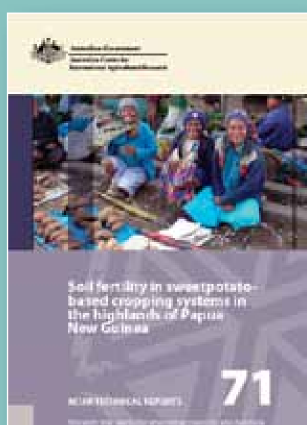
PROCEEDINGS

Use of the *FecB* (Booroola) gene in sheep breeding programs
Proceedings of the Helen Newton Turner Memorial International Workshop held in Pune, Maharashtra, India, 10–12 November 2008. The workshop was the conclusion of ACIAR projects that entailed more than a decade of research in India on improved meat sheep production.
S.W. Walkden-Brown, J.H.J. van der Werf, C. Nimbkar and V.S. Gupta (eds), ACIAR Proceedings 133, 238pp.

Spiny lobster aquaculture in the Asia–Pacific region
This publication is a compilation of papers presented at the International Symposium on Spiny Lobster Aquaculture held at Nha Trang, Vietnam in December 2008.
Kevin C. Williams (ed), ACIAR Proceedings 132, 162pp.

Village chickens, poverty alleviation and the sustainable control of Newcastle disease
These proceedings are a collection of papers presented at an international conference of 102 village poultry researchers and animal health specialists from eastern, southern and western Africa, South-East Asia, Europe and Oceania, in Dar es Salaam, Tanzania, in October 2005. The proceedings showcase the background, methodology and results of the AusAID-funded Southern Africa Newcastle Disease Control Project.
R.G. Alders, P.B. Spradbrow and M.P. Young (eds), ACIAR Proceedings 131, 236pp.

TECHNICAL REPORTS



Soil fertility in sweetpotato-based cropping systems in the highlands of Papua New Guinea
This report summarises the results from a pilot study on soil fertility management, and reviews sweetpotato-based cropping systems in the highlands of PNG. It also describes the lessons learnt from survey methodologies used to assess the socioeconomic and biophysical constraints to sweetpotato production in the area.
G. Kirchhof (ed.), ACIAR Technical Report 71, 126pp.

Characterisation of the tuna purse seine fishery in Papua New Guinea
The tuna fisheries in the western and central Pacific Ocean involve a variety of fishing activities, the most important of which are the industrial-scale purse seine, longline and pole-and-line fisheries. The analysis reported in this publication focuses on characterising the target and non-target catch of the purse seine fishery in the PNG exclusive economic zone.
S. Nicol, T. Lawson, K. Briand, D. Kirby, B. Molony, D. Bromhead, P. Williams, E. Schneiter, L. Kumoru and J. Hampton, ACIAR Technical Report 70, 44pp.

PROJECT FINAL REPORTS

PNG AND THE PACIFIC

Inland pond aquaculture in Papua New Guinea: assessment of the industry and evaluation of smallholder research and development needs *Paul T. Smith, Augustine Mobiha, Jacob Wani, Kine Mufuape, Kaupa Kia, Micah Aranka, Wally Solato and Hopa Simon, ACIAR Final Report FIS/2001/034, www.aciar.gov.au/publication/FR2009-20*

Potential economic impacts of the Varroa bee mite on the pollination of major crops in Papua New Guinea *Saul A. Cunningham, David C. Cook, Paul J. De Barro, Workneh Ayalew and Solomon Balagawi, ACIAR Final Report AH/2008/037, www.aciar.gov.au/publication/FR2009-26*

Assessing and extending schemes to enhance the profitability of the PNG coffee industry via price premiums for quality *Peter Batt, Roy Murray-Prior, Charles Dambui, Fabian Api and Leo Kepa Aroga, ACIAR Final Report ASEM/2004/042, www.aciar.gov.au/publication/FR2009-40*

Towards a sustainable oil palm industry in Papua New Guinea *P. Nelson, P. Carberry, S. Berthelsen, H. van Rees, I. Orrell and M. Banabas, ACIAR Final Report SMCN/2008/028, www.aciar.gov.au/publication/FR2009-47*

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