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.

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. ■

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

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