FINAL REPORT

Part 1 - Summary Details

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Part 3 – Final Report Guide

Background

Cotton is one of many agricultural industries heavily reliant on nitrogenous fertilizers and water storages to maintain high levels of production. Cotton-based farming systems are therefore labelled as potentially high-risk agricultural systems with respect to gases losses of nitrogen to the atmosphere, nitrate leaching which contribute to environmental pollution. The inefficient use of fertiliser applied nitrogen also reduces profitability.

Irrigated cotton grown on alkaline grey clay soils often use nitrogen fertilizer inefficiently, due largely to nitrogen loss (commonly 50 - 100 kg N ha^{-1}) through denitrification. These and the heavier black clays (Vertosols) are the dominant soils in the cotton growing region of Australia and with their high water holding capacity are ideal environments for denitrification and associated losses of nitrous oxide (N_2O) and N_2. The nitrogen gases emitted also include ammonia, but it is N_2O, a potent greenhouse gas with a Global Warming Potential (GWP) approximately 300 times that of carbon dioxide (CO_2), which has fuelled debate.

Concern has mounted in recent decades regarding the emission of greenhouse gases to the atmosphere through human activities. Modern agriculture has contributed to these emissions with the release of CO_2 from soils during land clearing and annual tillage operations. Nitrous oxide emissions are also on the increase nationally with the elevated use of nitrogenous fertilizers and irrigation in intensive crop production systems. Reducing the potentially large N emissions from these cropping systems has therefore been widely identified as a high priority for increasing profitability and reducing environmental pollution and is directly related to improved water and nitrogen use efficiency.

Quantifying total N gas loss from cotton soils is a difficult task, mainly due to the fact that N_2 is the principal gas in our atmosphere, thus measuring relatively small changes in N_2, compared to its atmospheric concentration is difficult. Nitrous oxide emissions are usually in concert with N_2, therefore, the ability to accurately measure N_2O emissions (normally only found at trace levels in our atmosphere) is a valuable quantitative indicator to the magnitude of N_2 emissions.

The proportion of N_2O contributing to the total nitrogen gas loss from cotton systems is unknown. Rochester (2003) has estimated that just over 1% of applied N is emitted as N_2O from alkaline grey clay soils in a cotton system. There is much speculation about the actual contribution of cotton cropping systems to global warming, a secondary objective of this study. The Intergovernmental Panel for Climate Change (IPCC) suggest 1.25% of applied fertilizer N as a general figure to estimate N_2O emissions. The only reported direct measurements of N_2O emissions from cotton soils in Australia were carried out during the first 10 weeks of the 2002-03 season by Grace et al. (2003) using a simple chamber technique and these ranged from 0.2-1.53% of applied N.

This final report provides details of both field and simulation experimentation to derive more reliable estimates of N losses, and specifically N_2O emissions from N fertilizer applied to cotton growing soils, with the potential for identifying management strategies for reducing total N losses, increasing nitrogen use efficiency and profitability.

A unique opportunity presented itself in 2003 to access state-of-the-art gas sampling equipment, from the Institute for Meteorology and Climate Research in Germany. The

Australian Greenhouse Office contributed funds with CRDC to bring this equipment to Australia for the 2003-04 growing season for a feasibility study in the use of continuous automated real time analysis of greenhouse gas emissions from cotton farming systems (CO_2, N_2O and CH_4). Subsequently, a dedicated piece of greenhouse gas monitoring equipment was purchased for use in Australia during the 2004/05 and 2005/06 seasons. This equipment will also be used in future seasons for monitoring greenhouse gas emissions in Australian cotton systems. This final report concentrates however on the principal objective, reducing N gas losses. Subsequent peer-reviewed publications will provide details of full greenhouse gas accounts for these systems.

Objectives

List the project objectives and the extent to which these have been achieved.

1. Determine emissions of the major N gases (N_2, NH_3, N_2O) and nitrate leakage from cotton-based systems in response to fertiliser and water management.

   Nitrous oxide emissions were explicitly determined, however it was not possible to determine NH_3 *with the equipment available. Losses of* N_2, NH_3 *and nitrate leaching were then estimated using a calibrated simulation model. The original proposal outlined using the drainage lysimeters for sampling, but these lysimeters were only commissioned at the end of the 2006 season.*

2. Develop BMPs to significantly reduce total N losses which complement existing management strategies for maximum productivity and sustainability.

   BMPs were developed directly from field experimentation i.e. comparison of fertiliser and organic based nitrogen fertiliser strategies, and through the use of a calibrated simulation models which allowed testing of management options with respect to timing, application method and the actual amounts of fertiliser.

3. Promotion of N loss reduction solutions and BMPs through extension networks and grower and consultant education.

   Extension networks, farming systems forums and regional workshops were the major avenues for dissemination of information and grower/consultant education. The project generated (and continues to generate) much interest with growers, especially the on-farm experimentation.

Methods

Objective 1 – Determine N loss through field experimentation

Field measurements using a portable automated gas analysis system were carried out at the Australian Cotton Research Institute (ACRI) at Narrabri in New South Wales during the 2003/04 and 2004/05 growing seasons, and at Brett Crothers farm (Cecil Plains Rd) via Dalby during the 2005/06 season. This portable system provides real-time analysis of greenhouse gas emissions, including N_2O, which can be used as an indicator of N_2 losses, usually the dominant loss.

Previous experiments measuring N_2O emissions from cotton soils (GCRC3C) have used simple closed plastic chambers which cover the soil. Gases are then manually sampled using syringes and analysis of the gas is performed in a laboratory using a gas chromatograph. This method has a number of disadvantages. It only allows for sampling at limited times e.g. if the field is too wet, the operator cannot enter the field to sample unless a walkway is built. The chambers are only placed on the soil surface, and may not fully represent the impact of plants on removing nitrogen and releasing carbon in the soil profile. Also, the simple chamber method is laborious and time consuming and only allows for periodic data collection.

The automated system used in this project is a modified design of closed chamber technique originally described by Butterbach-Bahl et al. (1997) and allows for data collection and analysis on a two hour cycle. Briefly, the measuring system consists of a gas chromatograph (SRI GC8610, Torrance, United States) equipped with a 63Ni electron capture detector (ECD) for N_2O analysis and flame ionization detector (FID) for CH_4 analysis, a LICOR Infrared gas analyzer (IRGA) for CO_2, a gas sampling system, a compressor, six-eight measuring chambers and computer for operating software and data storage. To meet the demand for portability, the system is entirely contained in two steel boxes. The equipment is then able to be transported in a purpose built trailer for field use (Figure 1).

Figure 1. Trailer based greenhouse gas sampling and analysis unit.

The chambers are built of aluminium with transparent acrylic panes and vary in size but capable of covering individual soil areas ranging from 1600-2500 cm^2 with a height of 25 cm. The panes have been covered with a transparent plastic coating (removable), which reduces heat, but allows for full transmission of light. The six chambers that were subsequently purchased cover a soil area of 2500 cm^2. The lids can be opened in a 90^o angle allowing rainfall to reach the soil surface covered by the chambers. The opening and closing of the lids is facilitated by pneumatic pistons attached to a compressed air line. The chambers have an internal temperature sensor, with 55 ^{o}C set as the threshold for opening to avoid any heat damage to plants. This setting can be changed. To accommodate actively growing plants, transparent extensions (with transparent solar shields as outlined above) can be fitted to increase the height of the chambers to 75 cm and 100 cm.

In the Narrabri growing seasons of 2003/04 and 2004/05, the extensions were not utilised and emissions were collected from the soil surface only, both before and after the plants within the chambers died (approximately mid-way through the growing season). In the Dalby growing season, three cotton plants actively grew in the chambers (extensions) for the entire season. Note that at Dalby, three chambers (with extensions) were placed on the bed, and three in the furrow, to assess the spatial differences in emissions (Figure 2), particularly as nitrate is a mobile compound and may move from the bed to the furrow. Also, the impact of water run applications of fertiliser N on emissions can be examined with chambers placed between the rows.

Figure 2. Gas sampling chambers (with and without 50 cm extensions) used at Dalby, Queensland for greenhouse gas emission experiment during the 2005/06 season.

The measuring chambers were all fixed on a stainless steel frame (80 mm height) which was driven into the ground, except in the case of the furrow chambers at Dalby. To ensure gas tightness, seals were fixed at all contact surfaces between lids, chambers, and frames. In addition, lids were pressed down by pneumatic cramps. On one side of the chambers, outlets for gas sampling have been fitted and each chamber. In the case of the original equipment (on loan), each of chambers were equipped with a small mixing fan in order to avoid gas gradients within the chamber, however this proved unnecessary (and a potential hazard) in irrigated systems, and were not part of the purchased equipment.

The entire unit was powered by a standard power supply and soil temperature and moisture status monitored using probes which accompany the sampling unit. A diesel generator was available if power fails for extended periods or remote sites require investigation for brief periods of time. Environscan continuous monitoring soil moisture probes (0-50 cm @ 10 cm intervals) were also used at the Dalby site, and installed in both the beds and furrows. Weather data was available from climate stations already in place and adjacent to the Narrabri and Dalby field sites.

Full assembly in the field of the measuring system and chambers takes approximately 3 hrs and is dependent on the state of the field at the time (e.g. if slightly wet, progress may slowed). Chambers are normally removed from the field for planting and some tillage operations. Spraying operations are usually accommodated with disruption of chambers.

The automatic gas sampling system consists of a sampling pump, a Valco sampling valve, valves for controlling sample airflow from the different chambers, relay boards, and mains receivers, all fixed in a portable sampling box. The whole system is controlled by a programmed computer card. The gas flow from the chambers to the automatic sampling system is 200 ml min^{-1}.

At the end of a 3-min flushing period, a 3 ml gas sample is taken from a chamber by a valve with sample loops. By switching the sample valves the chambers can be probed one after another based on a pre-programmed sequence determined by the operator. A total of 4 samples are taken from each chamber over a 120 minute period of time using the purchased 6 chamber configuration (Narrabri 2004/05, Dalby 05/06), after which the chambers are open for the same amount of time. Two calibration standards (400 ppb N_2O, 800 ppm CO_2 and 4 ppm CH_4) are run after every 6 samples.

Gas samples from the chambers are analyzed in real-time after being drawn through an Ascarite pre-column installed ahead of the analytical column in the gas chromatography to remove water vapour. To ensure constant conditions for gas chromatography in the field, the aluminium box was insulated, and temperature inside the box was kept constant at approximately 35°C by a thermostatically controlled fans. The trailer also has a fan and vents for circulating air, as well as a canopy to further reduce heat.

All three experiments concentrated on N_2O and CO_2 emissions as these cropping typically do not emit, but actually consume small amounts of CH_4. Methane measurements were discontinued after 3 weeks at Narrabri in 2003/04 after the initial background readings were established. Methane data was collected at Dalby in 2005/06

Nitrous oxide flux rates were calculated from the linear increase of N_2O concentration inside the chambers. All flux rates were corrected for temperature and air pressure. The detection limit for N_2O at ambient atmospheric N_2O background concentration (313 ppbv) was 5 ppbv. The detection limit for N_2O emission rates of the system was approximately 0.9 ug N_2O-N m^{-2} h^{-1}.

The following analytical specifications were used for N_2O detection using the SRI-TCD: stainless steel column packed with Hayesep N (3m, 1/8 inch, 60/80 mesh, Altech, Germany), oven temperature 55°C, detector temperature 350°C, carrier gas flux 40 ml min^{-1} N_2 (BOC Gases, Australia). These operating specifications were checked on a daily basis throughout the experimental period and fluctuations recorded and if necessary corrected to ensure quality control.

Data from the CO_2 analyzer were stored in 30s intervals. Calibration of the CO_2 analyzer was performed automatically using a standard gas and calculation of CO_2 fluxes were based on changes in CO_2 concentrations within the closed chambers measuring cycle using a linear regression approach similar to that for calculation of N_2O fluxes.

Experimental methodology and design

Narrabri 2003/04

The initial feasibility study (Narrabri 2003/04) using the eight chamber configuration (on loan) was performed on two adjacent cotton fields. One, a summer and winter fallow-cotton-wheat (wheat stubble incorporated) rotation, the other a cotton-vetch-cotton rotations. Both were part of an on-going long-term rotation trial of 12 years duration at the D1 block at ACRI and designated T3b and T1 respectively. All treatments in the D1 are minimum-tilled, and vetch is sprayed out before sowing cotton.

The grey alkaline clay (with a surface clay content of 56%) is typical of the region and the treatments have an average soil organic carbon content in the top 30 cm of 1.07% and a pH of

8.2. After soil testing for mineral nitrogen status in September 2003, the continuous cotton treatment received 140 kg N as anhydrous NH_3 on September 10, whilst the wheat-vetch-cotton treatment did not require additional fertilizer. Cotton was sown on 26 September, 2003. Irrigation was applied according to the normal schedule for the season. Four chambers were assigned to each treatment and each placed 5 metres apart along a single furrow.

The experiment also consisted of two distinct sampling phases. An extensive phase from 27 September, 2003 to 23 January, 2004 and a short-term intensive sampling event from 23 January 27 to February 2, 2004. During the extensive sampling, emissions were entirely dependent on normal agronomic procedures for irrigation and climatic conditions experienced during the 2003/04 cotton growing season. The purpose of the intensive sampling event was to mimic the impact of a significant irrigation event immediately after application of 200 kg N (applied as either banded granular or water-run urea) on N_2O emissions from these soils. This data is also invaluable in data estimation for periods during the course of the experiment when sampling was disrupted due to power or equipment failures. This latter data has not been analysed to data due to problems with the calibration standard.

Narrabri 2004/05

The second study at Narrabri 2004/05 utilised a newly purchased six chamber configuration and was performed on two adjacent cotton fields in the D1 Block at ACRI. One, a cotton-wheat-summer fallow-vetch-cotton rotation (designated T4a) with wheat stubble retained as standing stubble; the other, a cotton-winter fallow-cotton rotation. The continuous cotton treatment received 140 kg N on 10 September as anhydrous NH_3 whilst the wheat-vetch-cotton treatment did not require additional fertilizer, but organic N input was equivalent to 333 kg N ha^{-1}. Cotton was sown on 23 September, 2003. Irrigation was applied as per normal scheduling. Three chambers were assigned to each treatment and each placed 5 metres apart along a single furrow. Gas sampling commenced in early October, 2004 and finished in mid February, 2005.

Dalby 2005/06

The on-farm study was undertaken at the Benalla 3 field on Brett Crothers farm, west of Dalby on the Cecil Plains Rd. The field is furrow irrigated and has been under continuous cotton (with winter fallow) for 10 years. The block is conventionally tilled, with a spraying regime typical for cotton production in this area.

The black clay (with a surface clay content of 68%) is typical of the region and the treatments have an average soil organic carbon content in the top 10 cm of 1.0% and a pH of 8.5. Urea was banded on 10 and 30 August, 2005, at 92 and 70 kg N ha^{-1}, respectively. Cotton was sown on 2 November, with 30 kg N ha^{-1} NH_3 applied with irrigation water on 26 January, 2006, and an additional 15 kg N/ha water run urea applied on 24 February. A total of 207 kg N ha^{-1} was applied during the season, with post-sowing irrigation events restricted to a single occasion (24 February, 2006) due to fact the farm received exceptional rainfall during the season.

Three chambers were assigned to a single bed and placed five metres apart, and three to an adjacent furrow after skipping two rows. Gas sampling was undertaken from 9 October, 2005 to 23 March, 2006. Soil samples (0-10 cm) were periodically removed for nitrate analysis. Yield samples were also taken at harvest.

Objective 2 – Develop BMPs for reducing N loss using calibrated simulation models

It is both logistically and financially impossible to undertake large nitrogen and greenhouse gas monitoring experiments covering a wide range of sites across the cotton growing regions of Australia. To this end, over the last decade, a number of process-oriented simulation models have been developed which describe the interactions of the water, carbon and nitrogen cycles of terrestrial ecosystems in great detail. Relying on their outputs alone is not ideal, therefore the N_2O field observations provide an ideal dataset for calibrating related aspects of the N cycle in the individual simulation models.

By selecting a model which simulates biogeochemical processes with generic processes (i.e. non-site specific), and using select datasets for testing this model, it is then possible to perform simulation experiments as surrogates for field trials from diverse locations. The models we have selected for developing BMPs for reducing N loss have been widely tested and used in the international community. They are suitable for use in cotton systems of Australia and have the capacity for linkage to spatio-temporal databases. This ensures maximum coverage of the industry when developing region specific BMPs.

The DNDC (denitrification-decomposition) model is a complex simulation framework to model most of processes of C and N cycling in soils (Li et al. 1996). It was specifically developed to predict daily N_2O fluxes through the nitrification and denitrification pathways. It includes CO_2 production from decomposition of soil organic matter and root respiration, as well as CH_4 oxidation and production across a wide variety of agro-ecosystems.

The DNDC model consists of two components. The first, includes soil climate, crop growth and decomposition submodels, predicts soil temperature, water content, pH fluctuation, redox potential (Eh), and substrate concentration profiles based on ecological drivers (climate, soil properties, vegetation, and anthropogenic activity). The second component, consisting of nitrification, denitrification and fermentation submodels, predicts NO, N_2O, N_2, CH_4 and NH_3 fluxes based on soil environmental variables. Classic laws of physics, chemistry, or biology or empirical equations derived from laboratory observations were used in the model parameterize each specific reaction of C and N cycling.

The soil climate submodel of DNDC uses daily metrological data to predict soil temperature, water content and Eh profiles. Soil water fluxes uptake by plants is simulated for every hour of the day by integrating air temperature, precipitation, soil thermal and hydraulic properties, and oxygen status. A plant growth submodel simulates the growth of various crops from sowing to harvest, and predicts the biomass as well as N content of grain, shoot, and root of crops by integrating crop characters, climate, soil properties, and agricultural practices. Crop growth is also limited by mineral N and water availability in the root zone. Crop transpiration is estimated from crop growth and a crop-specific parameter for water use efficiency.

The hourly-time-step denitrification submodel of DNDC is activated by three conditions: rain events (when soil water content increases and or soil oxygen availability decreases), flooding/irrigation, and cold temperatures. DNDC requires daily climatic variables (minimum and maximum air temperature, solar radiation and precipitation), soil properties, including bulk density, texture, organic C and pH), and agricultural practices (crop type and rotation, tillage, fertilizer N application, manure amendment, irrigation, flooding, grazing and weeding). For regional estimates of N_2O emissions, the model utilises spatially and temporally referenced input data stored within GIS-compatible databases (Li et al., 1996).

The DNDC model has a user friendly interface and has been widely used as a decision support tool for estimating site and regional N emissions from agricultural lands (Saggar et al., 2004).

DNDC has been used in this project to simulate emissions at both Narrabri and Dalby sites.

The Water and Nitrogen Management Model (WNMM) (Li, 2002; Chen et al., 2002) is a spatially referenced biophysical model developed to simulate dynamic soil water movement and soil-crop C/N cycling under given agricultural management. It is a decision support system used in the identification of optimal strategies for managing water and fertilizer N under intensive cropping systems. To date its usage has concentrated on the simulation of wheat and maize systems in China and Mexico, however the model has been developed by the University of Melbourne and offers proximity for collaboration.

WNMM is similar to DNDC in its complexity and simulates the key processes of water and C/N dynamics in the surface and subsurface of soils, including evapotranspiration, canopy interception, water movement, groundwater fluctuations, soil temperature, solute transport, and crop growth, in response to agricultural management (crop rotation, irrigation, fertiliser application, harvest, and tillage). WNMM runs at a daily time step at a range of scales. Input data required by WNMM can be handled as individual layers within a geographic information system (GIS) e.g. soil type, land cover, climate, farm and field boundaries, as well as control data (starting date, period of simulation, initial land surface and soil conditions, agricultural management scenarios).

The crop growth module in WNMM is a simplification of the EPIC crop model, which applies the concepts of phenological crop development based on daily accumulated heat units, harvest index for partitioning grain yield, Monteith's approach for potential biomass, and stress adjustments for water, temperature and nitrogen availability in root zone of the soil profile. Total crop dry matter, leaf area index, root depth and density distribution, harvest index, crop yield, and N uptake are predicted. The crop N utilisation is estimated using a supply and demand approach.

WNMM simulates the transformations of several N species in agricultural fields, including mineralisation of fresh crop residue N and soil organic N, immobilisation of N in the microbial biomass, nitrification, NH_3 volatilisation, denitrification, N_2O and N_2 emissions. The WNMM N loss module has been favourably compared with DNDC (Li et al., 2005).

The performance of WNMM for simulating N losses, as well as soil water and nitrate dynamics, was tested at the Dalby site only.

Objective 3 – Promotion of BMPs

Workshops, forums, field days, conferences and websites were chosen as the principal means of dissemination of information on reducing N losses and greenhouse gas emissions to growers and consultants. These activities were undertaken with the assistance of the CRC fro Greenhouse Accounting, the Cotton Catchments Communities CRC and its predecessor, the Australian Cotton CRC.

Results

Objective 1 - Field experimentation

Narrabri 2003/04

Irrigation and rainfall events in late September, mid to late November and early December 2003 have been captured in the N_2O emissions data, with emissions from the fertilised treatment consistently higher than the green manure (vetch) treatment. A subset of this data is provided in Figure 3, with observations shown for a period commencing 17 days after the mineral fertiliser was applied.

This season was basically a feasibility study on the continued application of automated gas sampling and analysis equipment under extreme environmental conditions provided in an Australian summer. This resulted in some periods of time when the equipment was non-operational. The Institute for Meteorology and Climate Research of Germany provided a dedicated field operator at no expense for a period of 3 weeks in October 2003 to train operators, and continued to assist Australian researchers in this project.

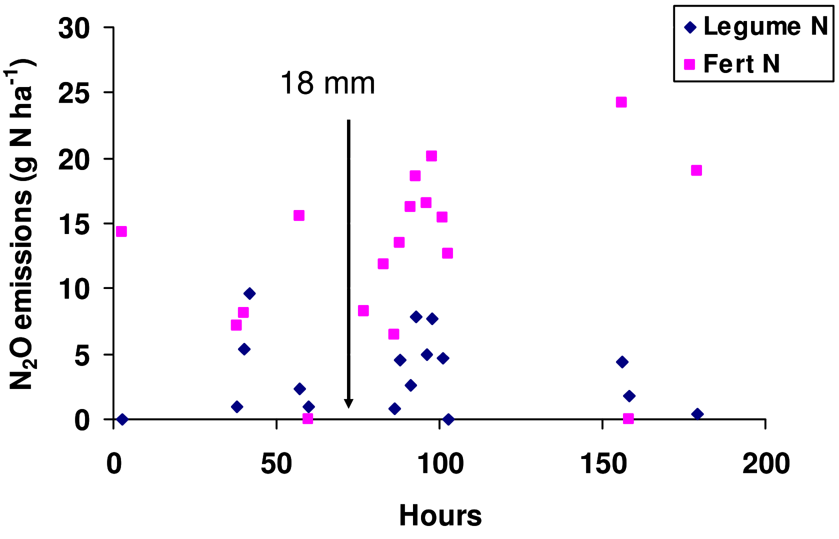


Figure 3. Representative N_2O emissions from a grey clay at Narrabri D1 (2003/04) either fertilized prior to sowing with either 140 kg N ha^{-1} as anhydrous NH_3 or from unfertilized field previously sown to vetch and supplying 100 kg N ha^{-1} as a green manure.

Background emissions from the fertilized field prior to the rainfall event on October 1 were double those of the green manured field (with no mineral fertiliser applied) where nitrate levels in excess of 80 ppm where found prior to sowing. The higher N_2O emissions from the fertiliser field does not necessarily suggest that the green manure treatment is better in terms of efficient production of N. Final yields for 2003/04 were 4 and 7 bales ha^{-1} for the cotton-vetch and cotton-winter fallow fields respectively, evidence that the amount of mineral nitrogen available in the legume system when limited compared to the fertilised system.

After a relatively small rainfall event, emissions from both fertilized and green manure fields increased (Figure 3), but such a small event would normally not have a major influence on soil water dynamics and emissions via denitrification. At this early stage in the season when this example was taken, it is difficult to determine whether denitrification is as yet a significant contributor to emissions.

The fact that the fertilized field received its nitrogen as ammonia and nitrification may as yet be incomplete would suggest that the N_2O emissions from the fertilized field at the early part of the season may have been via the nitrification pathway.

Narrabri 2004/05

The emissions of N_2O from the fertilised (140 kg N ha^{-1}) and green manured (333 kg N ha^{-1}) treatments in the D1 block at Narrabri for the 2004/05 season are presented in Figure 4. Rainfall events at the beginning of December 2004, and irrigation events in late December 2004 and January 2005 were captured, however emissions were not correlated with estimated increases in soil moisture.

Nitrous oxide emissions were determined from day 72 after the mineral fertiliser was added. During the subsequent 90 day sampling period, 112 g N ha^{-1} was emitted as N_2O from the fertiliser treatment, which was were slightly less than the green manure treatment (136 g N ha^{-1}). A total down time of 20 days was experienced during this experimental period. Background emissions were not significantly different from either of the cropping systems. The crop yields for the fertilised and green manure yield were 8 and 11 bales ha^{-1} respectively. The impact of applying the equivalent of an additional 200 kg N ha^{-1} in the green manure treatment, provided a significant yield boost with relatively little difference in N_2O emissions during the latter part of the season.

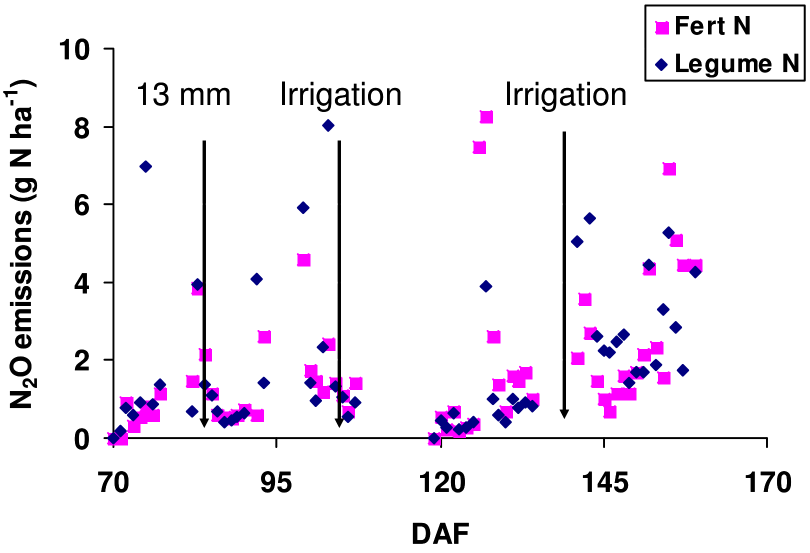


Figure 4. Observed N_2O emissions from a grey clay at Narrabri D1 (2004/05) which has been either fertilized prior to sowing with 140 kg N ha^{-1}as anhydrous ammonia or from an adjacent unfertilized field which has received the equivalent of 333 kg N ha^{-1} as green manure (DAF - Days after fertiliser applied).

Dalby 2005/06

The on-farm investigation at Dalby represents the most comprehensive of the three datasets collected in this project. Nitrous oxide missions depicted in Figure 5 are from 69-257 days after the initial fertiliser application on 10 August, 2005.

Note the incidence of rainfall and irrigation events (arrowed) which resulted in the surface soil being saturated, and the occasions (108, 144 and 170 DAF i.e. days after fertiliser was applied) where N_2O emissions significantly increased. Soil nitrate (0-10 cm) declined from 77 to 27 kg N ha^{-1} from 83 to 153 DAF.

Nitrous oxide emissions from the beds were 643 g N ha^{-1} during the measurement period of 188 days (with 14 days lost as downtime) whilst the N_2O emissions from the furrows were significantly higher at 967 g N ha^{-1}. This observation confirms the leakage of nitrate from beds to furrows and the higher potential for emissions where soils were saturated for longer periods for time.

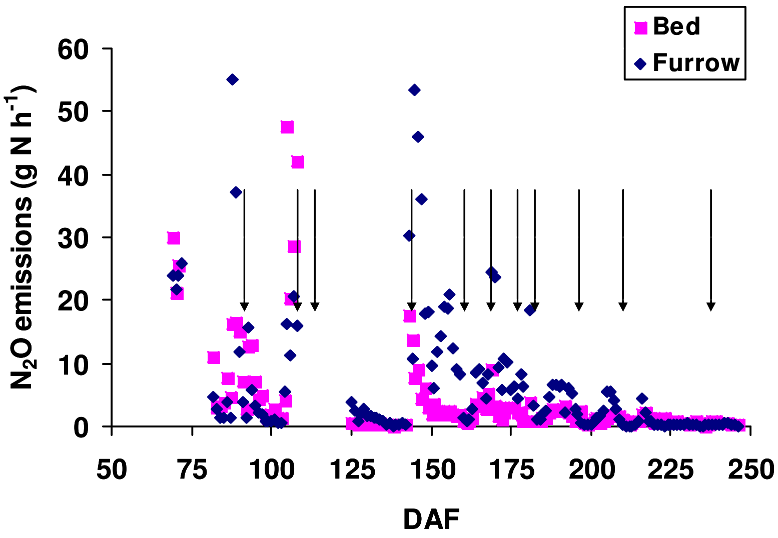


Figure 5. Observed N_2O emissions from a black clay at Dalby (2005/06) fertilised with a split application of 207 kg N (DAF – Days after fertiliser applied; arrows indicate rainfall and irrigation events which have restored the surface soil to saturation).

Objective 2 – BMPs

The observed N_2O emissions data collected during the latter part of the 2004/05 season at Narrabri, was used to calibrate the DNDC simulation model (version 8.9) and duplicate the emissions for that specific period of time. Only minor modifications were made to the model's original operating parameters. The simulated N_2O emissions from the mineral fertiliser and green manure treatments in Figure 6 are presented from the initial date of fertiliser application on September 10, 2004.

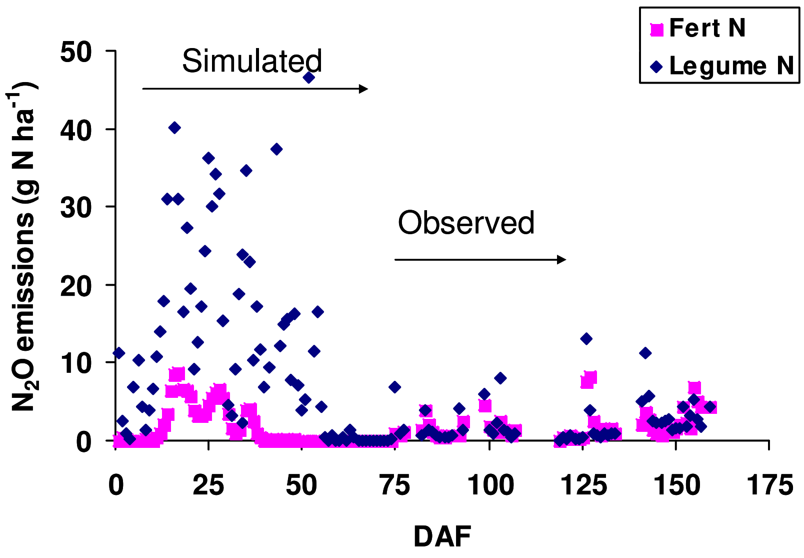


Figure 6. Simulated and observed nitrous oxide emissions from a grey clay at Narrabri D1 (2004/05) which has been either fertilized prior to sowing with 140 kg N ha^{-1}as anhydrous ammonia or from an adjacent unfertilized field which has received the equivalent of 333 kg N ha^{-1} as green manure (DAF - Days after fertiliser applied).

During the first 71 days after mineral fertiliser application, prior to the commencement of emissions monitoring, the model simulated that 115 g N ha^{-1} was emitted from the fertilised field. During the same time period, 1066 g N ha^{-1} was emitted from the field were 333 kg N ha^{-1} green manure was applied. Note that the simulated observations are of a similar order of magnitude to the early season observations for Narrabri (2003/04) in Figure 3.

By combining the simulated and observed N_2O data for the season, we are able to develop a comprehensive time sequence of the emissions. We estimate the seasonal N_2O emissions for the fertiliser and green manure treatments to be 227 and 1202 g N ha^{-1} respectively. If we assume all of the N_2O emitted is solely from the newly applied sources of nitrogen, the N_2O emissions for the 2004/05 season at Narrabri are equivalent to 0.16 and 0.36% of the total amount of N applied for the fertiliser and green manure treatments respectively.

These values are well below the default global average value of 1.25% of applied N used in calculations of N_2O emissions by the Intergovernmental Panel on Climate Change (IPCC), and consistent with field emissions data collected on similar soils in 2002/03 at ACRI by Grace et al. (2003).

The DNDC model also provides a simulated inventory of all N losses from the cropping system. Excluding NH_3 volatilization (which ranged from 7-17 kg N ha^{-1}) for the green manured and fertiliser field respectively, the total amount of N gas (N_2+N_2O) lost from the fertilised and green manured fields was 0.46 kg and 5 kg N ha^{-1} respectively (Figure 7), representing a small proportion of the total amount of N applied. This also represents an N_2/N_2O ratio of 2-4, an important parameter in the estimation of N losses from these species, which is of a similar magnitude to the ratio determined by laboratory incubation studies undertaken by Grace et al. (2003) on similar soils from Narrabri.

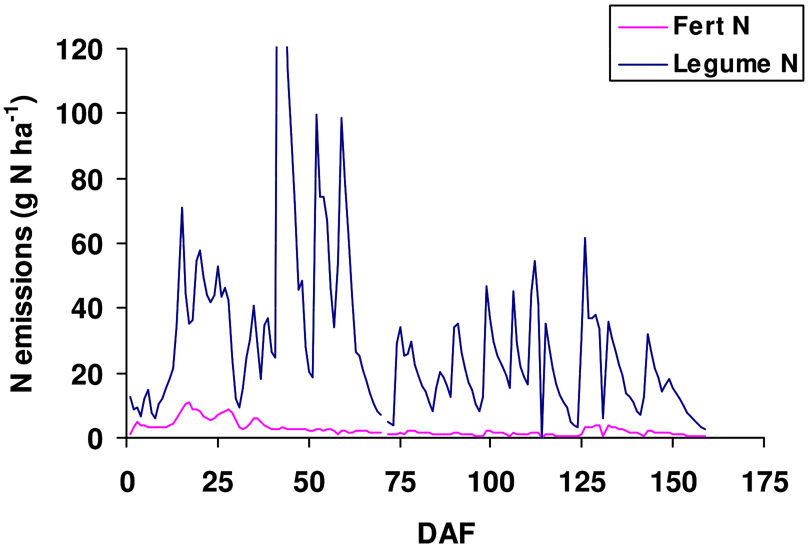


Figure 7. Simulated N emissions (excluding NH_3) from a grey clay at Narrabri D1 (2004/05) which has been either fertilized prior to sowing with 140 kg N ha^{-1}as anhydrous ammonia or from an adjacent unfertilized field which has received the equivalent of 333 kg N ha^{-1} as green manure (DAF - Days after fertiliser applied).

To test the utility of simulation for BMP development, the performance of the calibrated DNDC simulation model was further tested by comparing cotton yields and evaluating N losses for management strategies similar to those found at the D1 long-term rotation trial at Narrabri (Table 1). The only discrepancy was the slightly reduced yield simulated by DNDC for the treatment where green manure had been applied at 100 kg N ha^{-1}. Simulated leaching losses of 34 kg N ha^{-1} were consistent across all treatments and may be high based on past data, but these values should now be able to be confirmed using the lysimeters recently installed at Narrabri.

Table 1. Simulated N losses and crop yields on Narrabri grey clays receiving mineral or organic sources of N applications.

Green Manure	Fertiliser	Crop N Uptake	N_2O	N_2	Leach	Total Loss	Obs Yield	Sim Yield
			kg N ha^{-1}				bales ha^{-1}	
0	140	176	0.4	21	34	55	8	8
100	0	89	0.3	7	34	41	8	6
333	0	172	1.3	13	34	58	11	10

The use of green manures will increase N_2O emissions which have a direct impact on global warming, however the slow release of nitrogen from the organic source when compared to mineral N sources) reduces N_2 emissions, which improves nitrogen use efficiency and profitability. More work needs to be undertaken on the differential response of N_2 and N_2O emissions under these circumstances.

Dalby

To further test the utility of the DNDC simulation model to accurately simulate N losses and its capacity for developing nitrogen and greenhouse gas reduction strategies across the cotton regions of Australia, we used the same version of the model from the Narrabri simulations.

The only difference was the use of input variables for soil properties, climate and crop management for the Crothers farm. The internal parameters of the model remained the same. The simulated and observed N_2O emissions for 188 days during the 2005/06 season in Dalby are depicted in Figure 8. The simulated N_2O emission value of 1.37 kg N ha^{-1} is not significantly different from the observed value of 1.42 kg N ha^{-1} for this time period. The observed values for N_2O emissions are the mean value of the observations for the bed and furrow chambers.

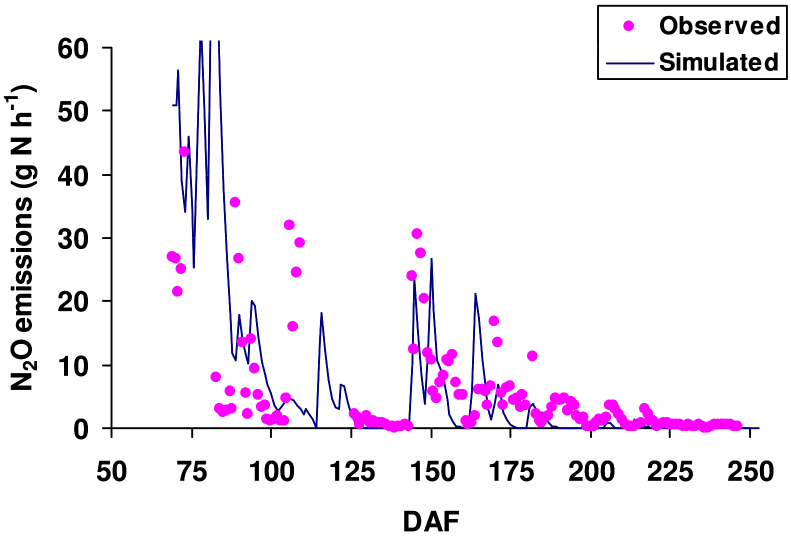


Figure 8. Simulated (using DNDC) and observed N_2O emissions from a black clay at Dalby (2005/06) fertilised with a split application of 207 kg N (DAF – Days After Fertiliser applied).

A visual comparison of the simulated and observed emissions of N_2O using the WNMM model is also presented in Figure 9.

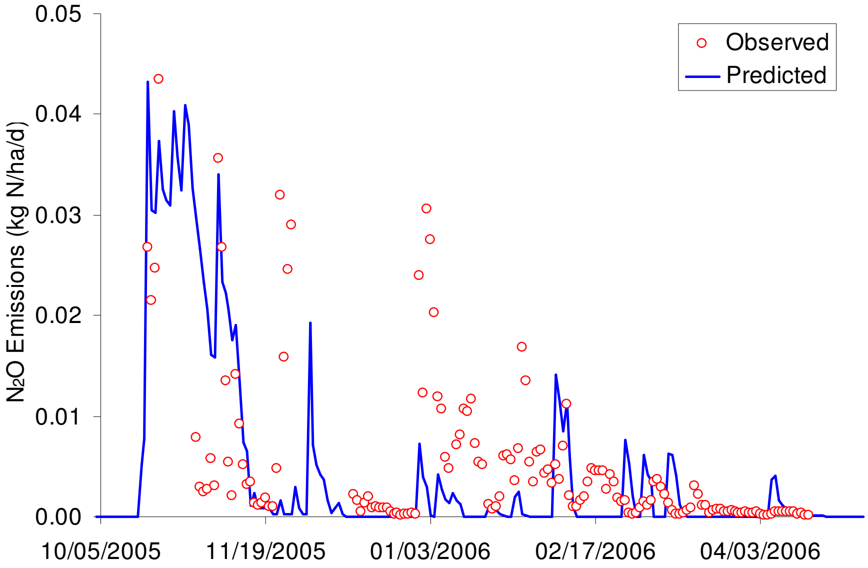


Figure 9. Simulated (using WNMM) and observed N_2O emissions from a black clay at Dalby (2005/06) fertilised with a split application of 207 kg N (DAF – Days after fertiliser applied).

This WNMM model was uniquely calibrated using the Dalby dataset, and similar trends in emissions over time are represented by both models. This provides evidence that in developing decision support systems for BMPs in cotton systems, we have a choice of accurate model which can potentially be linked to GIS thus ensuring regional coverage.

The reliability of DNDC (in Figure 8) to accurately simulate the observed N_2O emissions from the Dalby site confirms the models potential as an accurate means of simulating the emissions for the entire season. Simulated daily N_2O and N_2 losses for the full season at Dalby in 2005/06 are presented in Figure 10. Note the increase in all emissions during mid season when the soils were moist for long periods of time and soil temperate were also elevated.

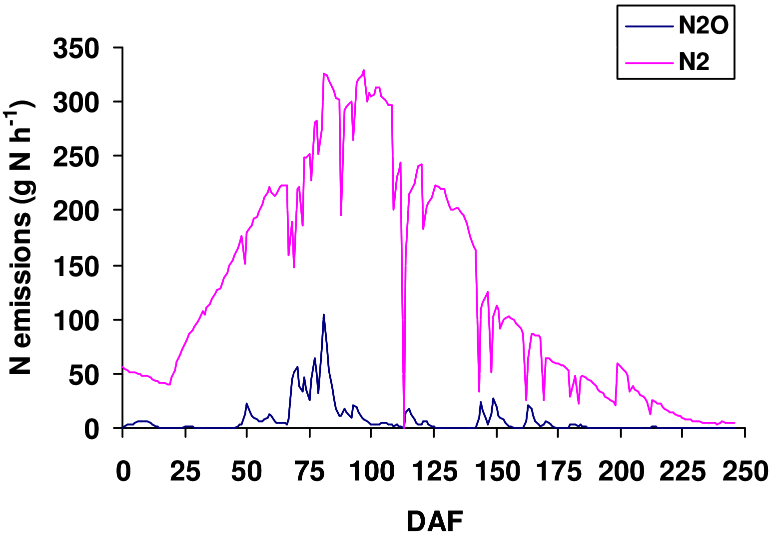


Figure 10. Simulated N_2O and N_2 emissions from a black clay at Dalby (2005/06) fertilised with a split application of 207 kg N (DAF – Days after fertiliser applied).

Total simulated emissions of N_2O and N_2 for the 2005/06 season were 1.7 and 30.7 kg N ha^{-1} respectively. The 1.7 kg N ha^{-1} for N_2O is equivalent to 0.83% of the fertiliser applied during the season, well below the default value of 1.25% determined by the IPCC. The fact that the 207 kg N ha^{-1} was a split application over many months has played a large part in the low % emission of N_2O. The total N emission ($N_2 + N_2O$) is equivalent to 16% of the N application for the season, and the N_2/N_2O ratio is 18/1, which is higher than the value determined in earlier laboratory incubations for Dalby soils.

BMPs can be now uniquely designed for each farmers fields using the calibrated simulation models tested in this project. An example of the impact of potential management options on yield, N loss and associated greenhouse gas emissions, is presented in Table 2. The simulated yields do not reflect any impacts of insect damage etc, and are moreso potential yields where all non agronomic constraints are removed. Climate data for the 2005/06 season at Dalby is used in this example, however, seasonal forecasts & irrigation management options can also be included to accommodate more options for water management.

Table 2. Simulated BMPs using DNDC to estimate nitrogen losses and crop yields on Dalby black clays with split applications of nitrogen.

Initial Fert	Plant	Fert N	Water N[a]	Total N	Crop N Uptake	N_2O	N_2	NH_3	Leach	Total Loss	FUE[b]	Sim Yield
Month					kg N ha^{-1}						%	ba
Aug	Nov	46/70	45[b]	161	141	3	32	37	23	94	42	8
Aug	Nov	92/70	45[b]	207	173	3	42	39	24	108	48	10[c]
Aug	Nov	92/70	45	207	188	3	43	18	25	89	57	12
Oct	Nov	46/0	115	161	145	3	35	23	34	95	41	13
Aug	Nov	92/0	115	207	185	3	36	25	34	98	53	14
Oct	Nov	92/0	115	207	186	3	36	26	35	100	52	14
Sept	Nov	92/0	115	207	186	3	36	25	34	98	53	14

[a] Water run urea unless specified, [b] Fertiliser N Use Efficiency = 1-(Total Loss/Applied) *100, [c] Water run NH_3, [d] Farmer's practice

The farmer's normal management practice generated the highest losses of nitrogen from the system, with NH_3 volatilisation (from the water run NH_3) being a significant loss. Use of urea instead of NH_3 is shown in the simulations to be preferred option, significantly reducing N loss and increasing final yield.

Nitrous oxide emissions remained relatively static for all options, regardless of the amount, timing of fertiliser application, or planting data.

The earlier the data of initial fertilisation application, the greater the potential for N_2 losses, however this is also a function of the amount of N applied at that time. Leaching losses increased as the amount of water run N was increased.

Nitrogen use efficiency (the ratio of crop N uptake to N available) remained relatively constant at 89%, but this includes uptake from both soil and fertiliser N sources.

Fertiliser N use efficiency (FUE) increased when fertiliser was applied closer to the actual planting date. The simulated FUE ranged from 41-57%, with the highest efficiency a result of a slight change to the farmer's normal management i.e. using urea instead of NH_3 in the irrigation water. FUE was significantly reduced when the initial application amount was halved, but by ensuring the dates of N application and planting are close, and a relatively large amount of water run urea is applied later in the season, potential yield (in this example) exceeded 12 bales.

We have demonstrated the utility of our approach for developing site specific BMPs, however some generic rules can be considered necessary for reducing N losses and maximizing productivity and profitability in cotton systems:

- Reduce the time between initial fertiliser application and planting
- Increase the amount of N applied later in the season relative to upfront applications
- Use urea in preference to NH_3 in water run applications
- Green manures may substitute for mineral sources of nitrogen

Outcomes

The principal outcome outlined in the original project application was to develop and promote BMPs for reducing N losses and associated greenhouse gas emissions.

To this end, this project has achieved all of its stated outcomes by:

- Explicitly determining N emissions and greenhouse gas emissions from typical cotton growing soils in response to both mineral and organic sources of fertiliser nitrogen.
- Developing the simulation framework for generating site-specific BMPs for reducing N losses and greenhouse gas emissions.
- Developing generic BMPs based on a combined experimental and simulation methodology.
- Developing a user friendly web based calculator of annual on-farm greenhouse gas emissions for cotton producers.
- Developing a prototype version of a web based management tool for reducing N and associated greenhouse gas emissions on a year by year basis.
- Increasing growers and consultants awareness in greenhouse gas emissions and their relationship to N loss management strategies.
- Educating growers and consultants in BMPs for reducing N loss and greenhouse gas emissions.
- Making positive use of on-farm participatory research methods and provided a site for grower interaction.
- Providing a unique opportunity to the cotton industry in acquiring state-of-the-art field equipment for the on-going monitoring of greenhouse gas emissions and thus the rare ability to provide realistic information for reducing N losses and associated greenhouse gas emissions.

With respect to technical advances, web-based calculators are for public use. The simulation models used in this project have been developed by third parties who have given permission for their continued use.

An experimental methodology has been developed and being used by other primary industries in Australia for monitoring all three greenhouse gases using a portable, trailer based, monitoring system.

We advise that is no change necessary to the IP register.

Conclusions

Nitrogen is an essential, but expensive input to cotton farming systems. It is also a significant source of a highly potent greenhouse gas, N_2O, which is emitted during the water-logging of soil profiles upon irrigation. Reducing nitrogen inputs, or the losses of applied nitrogen to the atmosphere is beneficial in terms of increased nitrogen use efficiency, profitability and reducing the global warming signature of cotton farming systems.

Our research on representative fields and farming systems has determined that N_2O emissions from irrigated cotton in Australia are well below the default global average for emissions used by the Intergovernmental Panel for Climate Change (IPCC).

Nitrous oxide emissions from typical BMP trials (on grey clays with a moderate N loss potential), receiving both mineral (100 kg N ha^{-1}) and organic (333 kg N ha^{-1}) sources of N, range from 0.16-0.36% of applied N. Total gaseous N losses (excluding NH_3) do not exceed 1.5% of applied N, however more experimental work on the actual contribution of N fertiliser to N_2 emissions is required before this combined value can be confirmed.

Typical on-farm N_2O emissions (on black clays with a relatively high N loss potential) where split applications of N are applied, do not exceed 1% of applied N, with total gaseous N losses (excluding NH_3) being 16% of the applied N. The practice of split applications is increasing across the cotton industry and its positive impact on reducing emissions is becoming obvious, however, as stated above, more work on the N_2 component of N loss is required before a final total N loss figure can be confirmed.

Substantial leakage of nitrate from beds to furrows was experimentally confirmed in the on-farm component of this project and is a significant source of N loss and N_2O emissions. This is an area of concern, considering the majority of growers use furrow irrigation, and requires further investigation.

The combined experimental and simulation methodology employed herein, has been successful in advancing our knowledge of a complex N cycle in cotton systems. More explicit analysis of these N losses (N_2, NH_3 and N leaching) using stable isotopes (^{15}N) has been approved by CRDC, in concert with AGO, and this is a logical extension of this project.

Site specific BMPs for reducing N losses and associated greenhouse gas emissions can be generated using the simulation models provided as part of this project, however a number of generic BMPs can be promoted.

- A reduction in the time between initial fertiliser application and planting is critical.
- Increasing the amount of fertiliser N applied later in the season (relative to upfront applications), will potentially increase yields and increase the overall nitrogen use efficiency for the season.
- Urea should be used in preference to NH_3 in water run applications.
- Green manures may substitute for mineral sources of nitrogen, however more work is required to confirm its utility as an alternative N source.

The project confirms that the cotton industries investment in soil N and greenhouse gas research has multiple benefits for both profitability and environmental protection, which extend beyond the industry itself.

Extension Opportunities

Plan to develop project technology and outcomes

A wide range of regional, national and international extension opportunities have alreadu been undertaken during the project to promote the technologies e.g.

1. Grace, P.R, Rochester, I., Griffin, T. (2004). Reducing nitrogen losses and greenhouse gas emissions for sustainable cotton farming, 12th Australian Cotton Conference, ACGRA, 10-12 August, 2004, Gold Coast.
2. Grace, P., Rochester, I & Kiese, R. (2004) Reducing greenhouse gases through sustainable farming practices – a win-win situation. CRDC Farming Systems Forum, November 29 & 30, 2004, Narrabri, Australia.
3. Grace, P. (2005) Global warming potential: More than just carbon, Centro de Energia Nuclear na Agricultura, 1 September, 2005, Piracicaba, Brazil.
4. Grace, P. (2005) Greenhouse gas emissions and cotton, Australia Cotton CRC Final Review, August 15, 2005, Narrabri, Australia.
5. Grace, P. (2005) Australian Cotton Trade Show, 25 & 26 May, 2005, Moree, Australia.
6. Grace, P. (2005) Clever crops and greenhouse gases - Improving agriculture's capacity to reduce greenhouse gas emissions, Plenary, Grain Weeks, April 5, 2005, Brisbane, Australia.
7. Grace, P. (2005) Measuring, monitoring and inventory – Australasian approaches. Third USDA Symposium Greenhouse Gases & Carbon Sequestration in Agriculture and Forestry, March 21-24, 2005, Baltimore, USA.
8. Grace, P. & Tate, K. (2004) Estimating greenhouse gas fluxes and mitigation impacts – Australian and New Zealand Experiences, Joint Symposium of Soil Science Society of America and Canadian Society of Soil Science, Field-to-Region Links of Soil Carbon Dynamics, Greenhouse gas Fluxes and Agricultural Mitigation Practices, Seattle, USA, November 1, 2004.
9. Grace, P. (2004) Processes, data and models - Integrated approaches to mitigating greenhouse gas emissions from agricultural soils, Western Australia Department of Agriculture, Perth, Australia, October 20, 2004.
10. Chen, D., Li, Y., Grace, P. and Eckard, R. (2005) N_2O emissions from agricultural lands: A synthesis of simulation approaches. Proceedings of the Fourth International Symposium on Non-CO_2 Greenhouse Gases (NCGG-4), Science, Control, Policy and Implementation. Utrecht, The Netherlands, July 4-6. 2005.
11. Grace, P. (2006) Nitrous oxides and greenhouse gas emissions. Cotton Catchments CRC Field Day - Nitrogen fertiliser management and the associated environmental and economic costs, Dalby & St George, Queensland, 1-2 June, 2006.
12. Grace, P. (2006) Alternatives to fertiliser applications. Cotton Catchments CRC Field Day - Nitrogen fertiliser management and the associated environmental and economic costs, Dalby & St George, Queensland, 1-2 June, 2006.
13. Grace, P. (2006) Greenhouse gas emissions from a cotton crop and carbon life-cycle of a cotton shirt. CRDC Farming Systems Forum, Sept 14, 2006, Narrabri, Australia.

Exposure of the project was also provided by the Greenhouse in Agriculture Research News newsletter, issued was quarterly during the life of the CRC for Greenhouse Accounting (now twice a yearly with subscription of about 200, nationally and internationally).

The CRC for Greenhouse Accounting Agricultural Industry Liaison Panel (2004-2006) - twice yearly forum involving policy, industry and research in which both CRDC and Cotton Australia participated.

Promotional and educational activities will continue in collaboration with CRDC and CRC Cotton Catchment Communities. The portable greenhouse gas monitoring equipment itself has proved to be a draw card at field days and a continuing experiment assessing greenhouse gas and nitrogen emissions will ensure use and promotion of the technology for ongoing research and develop purposes within in the industry is fully exploited.

The simulation models used in this project have the capacity to be used within a GIS framework, therefore, the capacity to develop region specific BMPs, with the potential for a web-based system will be explored in 2007.

Plan for future presentation and dissemination of the project outcomes

A greenhouse gas calculator is now available via a website (www.isr.qut.edu.au) for growers to quantify farm based greenhouse gas emissions. A second calculator is being produced which allows growers to pre-test management strategies which may potentially reduce emissions and N loss. These calculators will be maintained and updated by the Institute for Sustainable Resources at QUT.

There is also scope for dissemination of information through the Healthy Soils for Sustainable Farming (HSSF) initiative (Land & Water Australia) which both QUT and CRC Cotton Catchment Communities are involved as core project members. The LWA QUT project, coordinated by Peter Grace, includes collection of greenhouse gas samples (N_2O and CO_2) from a wide variety of farming systems through farmer networks.

Plan for future research

A continuation of this project has been approved by CRDC (QUT2) and will focus on collection of detailed N loss and greenhouse gas information across all of the cotton growing regions. The new project will involve a participatory on-farm research network collected gas samples, which is ideal for extending the impacts of the current project and promoting the BMPs.

Publications arising from the research project and publication plan.

Peer-reviewed journal articles outlining all aspects of the project are being completed for submission to international journals in 2007.

Current publications include:

1. Grace, P.R., Rochester, I, Hulugalle, N., Weier, K., Kiese, R., Butterbach-Bahl, K, Chen, D & Eckard, R. (2003) Full greenhouse gas profiling from irrigated soils in the cotton growing region of Australia, 2nd Joint Australia and New Zealand Forum on Non-CO_2

greenhouse emissions from agriculture, Australian Greenhouse Office, 20-22 October 2003, Melbourne, Australia.

2. Grace, P.R., Rochester, I, Hulugalle, N., Weier, K., Kiese, R., Butterbach-Bahl, K, Chen, D & Eckard, R. (2003) Full greenhouse gas profiling from irrigated soils in the cotton growing region of Australia, 2nd Joint Australia and New Zealand Forum on Non-CO_2 greenhouse emissions from agriculture, Australian Greenhouse Office, 20-22 October 2003, Melbourne, Australia.
3. Greenhouse in Agriculture. Research News, December 2004. http://target10.com.au/greenhouseNewsletter/index2.aspx
4. Measuring greenhouse gas emissions from cotton crops. The Australian Cotton Grower 25(5) October-November 2004, p 8-9, Greenmount Press, Toowoomba.
5. Galbally, I., Kevin, Phillips' F., Baigent, R., Barker-Reid, F., Gates, W., Grace, P., Meyer, M., Eckard, R., Leuning, R., Chen, D., Week, I., Bentley, S., & Griffith, D. (2005) Environmental and management drivers of non-CO_2 greenhouse gas emissions in Australian agro-ecosystems. Environmental Sciences, 2, 133-142.
6. Chen, D., Eckard, R., Edis, R., Grace, P. and Li, Y. (2005) N_2O emissions from agricultural lands: a synthesis of simulation approaches. Fourth International Symposium on Non-CO_2 Greenhouse Gases (NCGG-4): Science, Control, Policy and Implementation (Ed. A. van Amstel), 4-6 July 2005, Utrecht, The Netherlands, CD-ROM.
7. Grace, P., Rochester, I., & Horn, P. (2006) Economic and environmental costs of greenhouse gases for cotton farming. Information Sheet, Cotton Catchments CRC.

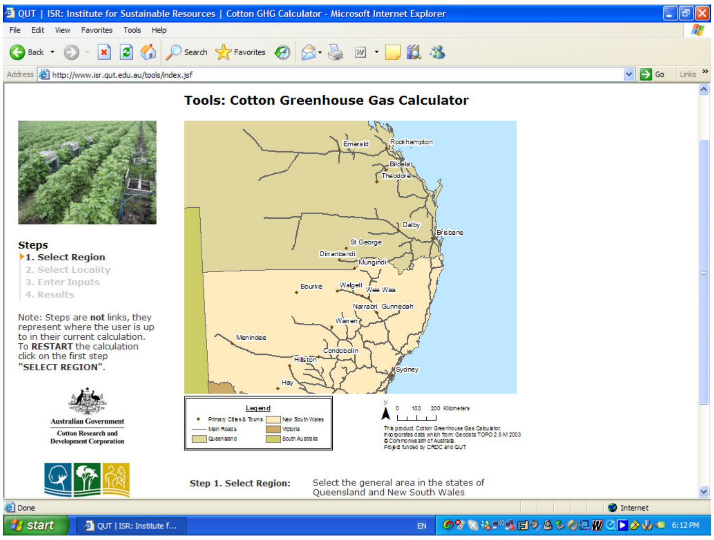
Online resources

Pictorials are available at

http://www.greenhouse.unimelb.edu.au/Narrabri2.htm
www.isr.qut.edu.au/publications/isr/rm_3.jsp

The Cotton Calculator (version 1) is available at http://www.isr.qut.edu.au/tools/index.jsp and provides growers with an inventory of emissions.

The web version is available for CRDC to post on any website or the link can be used.



QUT | ISR: Institute for Sustainable Resources | Cotton GHG Calculator - Microsoft Internet Explorer

Address http://www.isr.qut.edu.au/tools/index.jsf

Tools: Cotton Greenhouse Gas Calculator

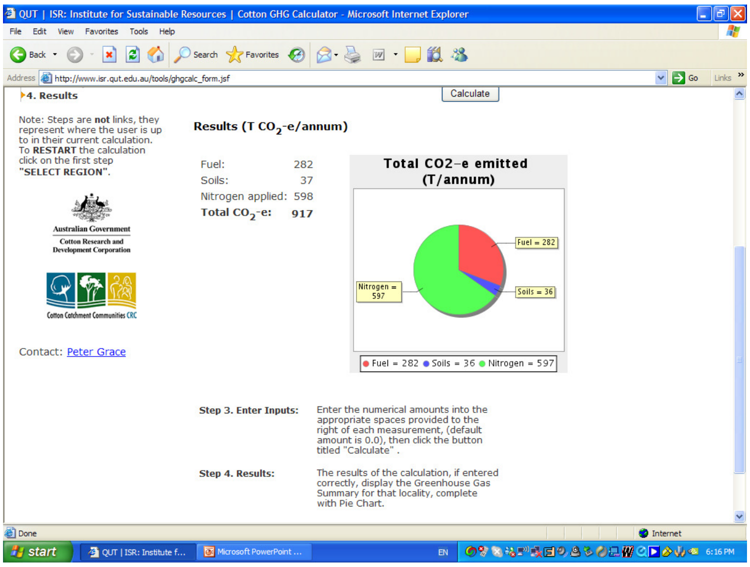
Steps
1. Select Region
2. Select Locality
3. Enter Inputs
4. Results

Note: Steps are **not** links, they represent where the user is up to in their current calculation. To **RESTART** the calculation click on the first step **"SELECT REGION"**.

Step 1. Select Region: Select the general area in the states of Queensland and New South Wales

This product, Cotton Greenhouse Gas Calculator, incorporates data which from: Geodata TOPO 2.5 M 2003 ©Commonwealth of Australia. Project funded by CRDC and QUT

The summary outputs screen provide graphical representation of greenhouse gas emissions, including associated N losses from soils in a season.



4. Results

Note: Steps are **not** links, they represent where the user is up to in their current calculation. To **RESTART** the calculation click on the first step **"SELECT REGION"**.

Contact: Peter Grace

Results (T CO_2-e/annum)

Fuel: 282
Soils: 37
Nitrogen applied: 598
Total CO_2-e: 917

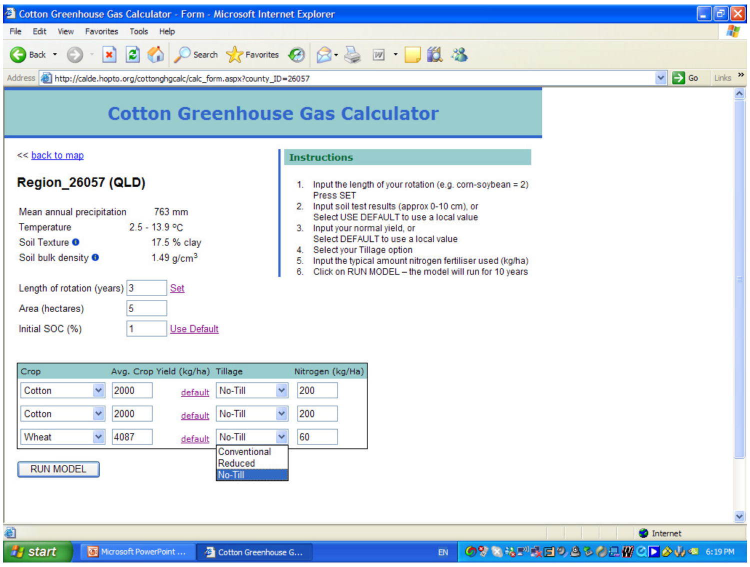
Total CO2–e emitted (T/annum)

● Fuel = 282 ● Soils = 36 ● Nitrogen = 597

Step 3. Enter Inputs: Enter the numerical amounts into the appropriate spaces provided to the right of each measurement, (default amount is 0.0), then click the button titled "Calculate" .

Step 4. Results: The results of the calculation, if entered correctly, display the Greenhouse Gas Summary for that locality, complete with Pie Chart.

Cotton Calculation (version 2), see screen shot below, is not yet available on the website, will allow growers to describe their rotation and inputs for each year. It also is a decision support tool for farmers to assess potential emissions before they choice a particular management strategy.



Cotton Greenhouse Gas Calculator

Region_26057 (QLD)

Mean annual precipitation	763 mm
Temperature	2.5 - 13.9 °C
Soil Texture	17.5 % clay
Soil bulk density	1.49 g/cm³

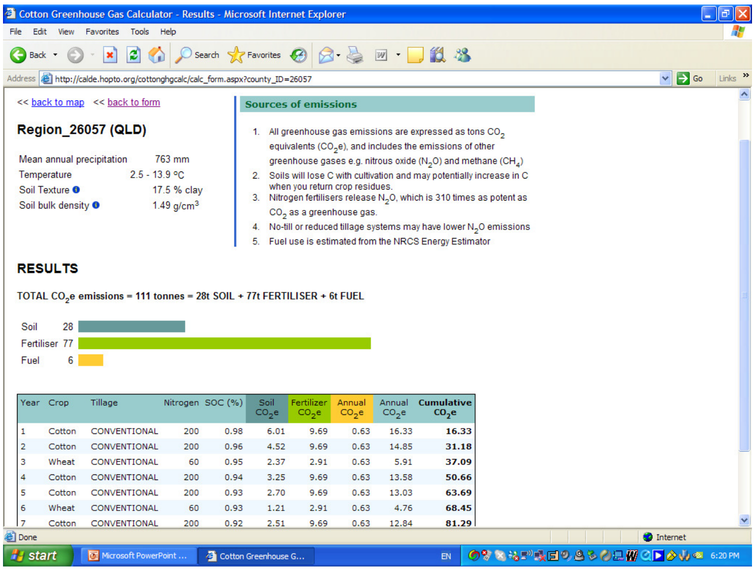
Length of rotation (years) 3
Area (hectares) 5
Initial SOC (%) 1

Crop	Avg. Crop Yield (kg/ha)	Tillage	Nitrogen (kg/Ha)
Cotton	2000	No-Till	200
Cotton	2000	No-Till	200
Wheat	4087	No-Till	60

Instructions

1. Input the length of your rotation (e.g. corn-soybean = 2) Press SET
2. Input soil test results (approx 0-10 cm), or Select USE DEFAULT to use a local value
3. Input your normal yield, or Select DEFAULT to use a local value
4. Select your Tillage option
5. Input the typical amount nitrogen fertiliser used (kg/ha)
6. Click on RUN MODEL – the model will run for 10 years

Greenhouse gas emissions data and associated N losses in version 2 are displayed on an annual basis, thus providing a decision support framework for growers to make seasonal management decisions to minimise greenhouse gas emissions and associated N losses.



http://calde.hopto.org/cottonghgcalc/calc_form.aspx?county_ID=26057

<< back to map << back to form

Region_26057 (QLD)

Mean annual precipitation	763 mm
Temperature	2.5 - 13.9 °C
Soil Texture	17.5 % clay
Soil bulk density	1.49 g/cm^3

Sources of emissions

1. All greenhouse gas emissions are expressed as tons CO_2 equivalents (CO_2e), and includes the emissions of other greenhouse gases e.g. nitrous oxide (N_2O) and methane (CH_4)
2. Soils will lose C with cultivation and may potentially increase in C when you return crop residues.
3. Nitrogen fertilisers release N_2O, which is 310 times as potent as CO_2 as a greenhouse gas.
4. No-till or reduced tillage systems may have lower N_2O emissions
5. Fuel use is estimated from the NRCS Energy Estimator

RESULTS

TOTAL CO_2e emissions = 111 tonnes = 28t SOIL + 77t FERTILISER + 6t FUEL

Soil 28
Fertiliser 77
Fuel 6

Year	Crop	Tillage	Nitrogen	SOC (%)	Soil CO_2e	Fertilizer CO_2e	Annual CO_2e	Annual CO_2e	**Cumulative CO_2e**
1	Cotton	CONVENTIONAL	200	0.98	6.01	9.69	0.63	16.33	**16.33**
2	Cotton	CONVENTIONAL	200	0.96	4.52	9.69	0.63	14.85	**31.18**
3	Wheat	CONVENTIONAL	60	0.95	2.37	2.91	0.63	5.91	**37.09**
4	Cotton	CONVENTIONAL	200	0.94	3.25	9.69	0.63	13.58	**50.66**
5	Cotton	CONVENTIONAL	200	0.93	2.70	9.69	0.63	13.03	**63.69**
6	Wheat	CONVENTIONAL	60	0.93	1.21	2.91	0.63	4.76	**68.45**
7	Cotton	CONVENTIONAL	200	0.92	2.51	9.69	0.63	12.84	**81.29**

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Chen D, White RE, Li Y, Edis R, Zhang JB, Li BG, Zhang YM, Huang YF, Cai GX, Hu KL, Li GT, Zhu AN, Zeng JH and Ding H. 2001. ACIAR Project Annual Report (2000.6-2001.9): Water and nitrogen management to increase agricultural production and improve environmental quality (LWR1/96/164). The University of Melbourne (Australia), The Chinese Academy of Sciences (P.R.China), and China Agricultural University (P.R.China).

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Saggar S., Andrew R.M., Tate K.R., Hedley C.B., Rodda N.J. and Townsend J.A. 2004. Modelling nitrous oxide emissions from dairy-grazed pastures. Nutrient Cycling in Agroecosystems 68: 243-255.

Part 4 – Final Report Executive Summary

Cotton is one of many agricultural industries heavily reliant on nitrogenous fertilizers and water storages to maintain high levels of production. Cotton-based farming systems are therefore labelled as potentially high-risk agricultural systems with respect to gases losses of nitrogen to the atmosphere, nitrate leaching which contribute to environmental pollution. The inefficient use of fertiliser applied nitrogen also reduces profitability.

Concern has mounted in recent decades regarding the emission of greenhouse gases to the atmosphere through human activities. Modern agriculture has contributed to these emissions with the release of CO_2 from soils during land clearing and annual tillage operations. Nitrous oxide (N_2O) emissions are reportedly on the increase with the elevated use of nitrogenous fertilizers and irrigation in crop production systems.

Reducing the potentially large N emissions from these cropping systems has therefore been widely identified as a high priority for increasing profitability and reducing environmental pollution and is directly related to improved water and nitrogen use efficiency.

Our research has confirmed that management practices currently being promoted across the cotton industry are making a positive contribution to reducing greenhouse gas emissions from Australia soils.

Experimental data has confirmed that typical seasonal on-farm emissions of the greenhouse gas, N_2O, which is over 300 times more potent as CO_2, from irrigated cotton systems in Australia and using split applications of nitrogen, are less than 1% of the total nitrogen applied. This figure is well below the default global average for emissions used by the Intergovernmental Panel for Climate Change (IPCC) in developing greenhouse gas inventories. The total loss of gaseous nitrogen using a typical split application (excluding ammonia) is estimated to be about 16%.

The following Best Management Practices have been identified for reducing nitrogen losses and associated greenhouse gas emissions:

- A reduction in the time between initial fertiliser application and planting is critical.
- Increasing the amount of fertiliser N applied later in the season (relative to upfront applications), will potentially increase yields and increase the overall nitrogen use efficiency for the season.
- Urea should be used in preference to NH_3 in water run applications.
- Green manures may substitute for mineral sources of nitrogen, however more work is required to confirm its utility as an alternative N source.

Reducing greenhouse gas emissions requires an estimate of your on-farm emissions. A user-friendly web site for estimating the emissions from fuel, soil and fertiliser sources on Australian cotton farms is now available at www.isr.qut.edu.au/tools/index.jsp