The difficulties in reducing both N_2O and CO_2 emissions from Australian subtropical agricultural systems

Neil Huth and Peter Thorburn, *CSIRO Sustainable Ecosystems*
Bruce Radford and Craig Thornton, *Queensland Department of Environment and Resource Management*

Introduction

One method for increasing the sequestration of carbon within agricultural soils is to increase crop productivity and therefore carbon input into the soil. However, if this is achieved via nitrogenous fertilisers, there is a potential tradeoff between decreased carbon emissions and increased nitrous oxide emissions (N_2O) due to the increased soil carbon and nitrogen. An alternative is to incorporate leguminous crops into cropping rotations to provide a biological source of nitrogen. However, the likely impacts on carbon input and nitrous oxide emission when replacing cereal crops with legumes is unknown. Consequently, an analysis of the likely impacts has been undertaken for a subtropical dryland cropping system in Queensland, Australia where soil, climate and management are conducive to denitrification losses.

Methods

A series of scenarios embracing a range of cropping rotations, nitrogen fertilisers and leguminous crops were tested using the Agricultural Production Systems Simulator (APSIM) (Keating et al. 2003). The model configuration was tested using long term data from the Brigalow Catchment Study site near Theodore, Queensland, Australia (24.81° S, 149.80° E) (Cowie et al. 2007). A wide range of data was used in testing the model for the major terms in the carbon, nitrogen and water balances (Radford et al 2007; Thornton et al 2007).

The model configured and tested above was used to estimate the changes in soil C and N_2O emissions for the following cropping systems
1) WS – Wheat and Sorghum with no fertiliser
2) WS+N – Wheat and Sorghum with fertiliser
3) WS+N Split – Wheat and Sorghum with a split application of fertiliser
4) CS – Chickpea and Sorghum, Sorghum fertilised
5) WM – Wheat and Mungbean, Wheat fertilised

Simulations were undertaken using weather data from 1950 to 2005 to provide a longer sample of local climatic conditions. Partial accounting for greenhouse gas emissions and economic return was applied to provide a simple comparison of the relative performance of the scenarios.

Results and Discussion

APSIM was able to adequately describe the major processes and resultant changes in crop productivity and soil C and N content within the surface (0-0.3 m) soil layers for the chosen test dataset (Figure 1). Although neither denitrification nor nitrous oxide emissions were measured as part of this long term study, confidence in the model predictions of these processes can be obtained by comparing the model predictions of the main drivers of denitrification such as C, water and N and by accounting for all N loss mechanisms as part of the overall observed decline in soil N (Figure 2).
A summary of the results from the scenario analyses are included in Table 1. Increasing productivity via fertilisers or legumes decreased the CO_2 production from these systems. Fertiliser application increased N_2O losses, though this was slightly lower when split applications where used to better match the time of crop N demand. The introduction of mungbean crops reduced fertiliser application and N_2O losses and increased profitability. However, the use of chickpea in these systems resulted in similar N_2O emission and higher CO_2 emission than fertilised systems due to its low level of stubble cover, and therefore, adverse impact on fallowing efficiency.

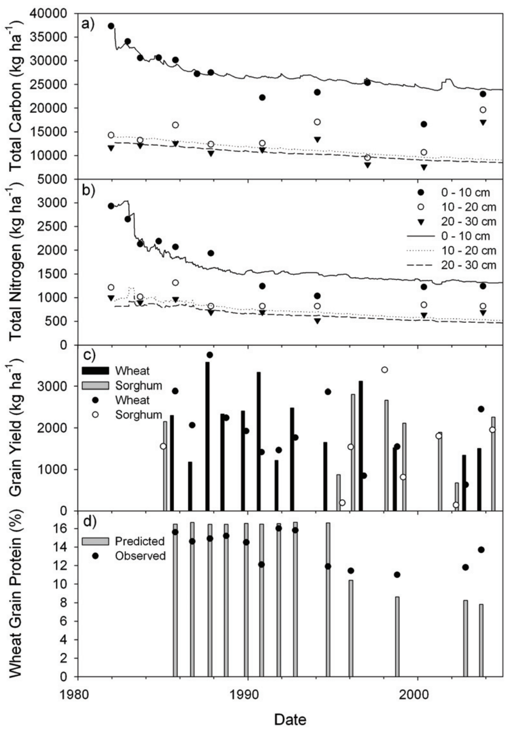

Figure 1: Observed and predicted time courses of a) soil carbon and b) total soil nitrogen (observed as symbols and predicted as lines, see legend) as well as c) grain yield and d) wheat grain protein content (observed as symbols, predicted as bars).

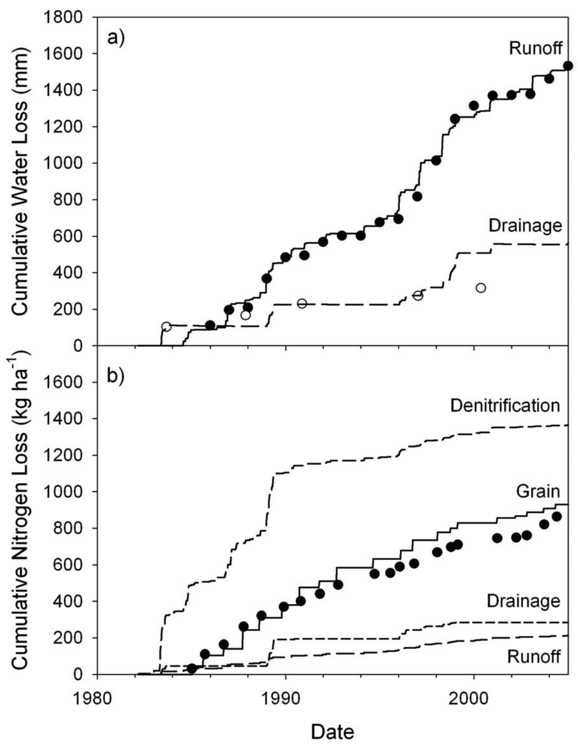

Figure 2: Observed and predicted accumulated losses for a) water (runoff and drainage) and b) nitrogen (export in grain, runoff water or drainage and denitrification). In both figures observations are as symbols and predictions as lines.

Table 1: Simulated (1950-2005) average production, fertiliser N input, CO_2 and N_2O emissions and economic return for the 5 management scenarios. Scenarios are described within the text.

	WS	WS+N	WS+N split	CS	WM
Average grain yield (kg ha^{-1}) (number of crops)					
Winter Crop	847 (48)	2484 (34)	2552 (32)	1805 (32)	2564 (33)
Summer Crop	1460 (56)	3539 (51)	3553 (51)	3203 (42)	1438 (55)
Average annual N application (kg ha^{-1} y^{-1})					
Winter Crop	0.0	32.6	31.1	0.0	25.6
Summer Crop	0.0	55.1	52.6	36.4	0.0
Total	0.0	87.7	83.7	36.4	25.6
Average annual emissions (t CO_2e ha^{-1} y^{-1})					
Carbon Dioxide	0.96	0.48	0.50	0.63	0.49
Nitrous Oxide	0.27	1.20	1.00	1.03	0.70
Total	**1.23**	**1.68**	**1.50**	**1.67**	**1.20**
Average annual gross margin ($ AUD ha^{-1} y^{-1})					
Winter Crop	19.5	237.2	236.1	331.2	251.3
Summer Crop	-15.0	304.3	310.9	221.5	526.4
Total	**4.5**	**541.5**	**547.0**	**552.7**	**777.7**
Economic return on emission ($ AUD t CO_2e $^{-1}$)	**3.6**	**323.2**	**364.2**	**331.3**	**650.2**

Conclusion

Scenario analyses of alternative management systems including the use of fertiliser or legume grain or forage crops within cereal rotations demonstrated that soil carbon can be managed to some degree via simple changes in agronomic practice. The use of legumes within cereal rotations was not always as effective in reducing nitrous oxide emissions as improved fertiliser practice. In fact, the use of chickpea crops to replace wheat crops did not reduce nitrous oxide emission relative to fertilised systems and did not assist in increasing soil C. The fact that some interventions proved counterproductive due to complex feedback mechanisms highlights the need for detailed models which capture the links between water, carbon, nitrogen and management.

References

Cowie, B.A., Thornton, C.M. and B.J. Radford (2007) The Brigalow Catchment Study: I. Overview of a 40-year study of the effects of land clearing in the brigalow bioregion of Australia. Australian Journal of Soil Research 45: 479-495.

Keating, B.A., Carberry, P.S., Hammer, G.L., et al (2003) An overview of APSIM, a model designed for farming systems simulation. European Journal of Agronomy 18: 267-288.

Radford, B.J., Thornton, C.M., Cowie, B.A. and M.L. Stephens (2007) The Brigalow Catchment Study: III. Productivity changes on brigalow land cleared for long-term cropping and for grazing. Australian Journal of Soil Research 45: 512-523.

Thornton, C.M., Cowie, B.A., Freebairn, D.M. and C.L. Playford (2007) The Brigalow Catchment Study: II. Clearing brigalow (Acacia harpophylla) for cropping or pasture increases runoff. Australian Journal of Soil Research 45: 496-511.

CSIRO

Further information

contact: Neil Huth
phone: (07) 4688 1421
email: neil.huth@csiro.au

www.csiro.au