# An Approach To Assess And Manage Nutrient Loads In Two Coastal Catchments Of The Eurobodalla Region, NSW, Australia

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**EXTENDED ABSTRACT**

This paper describes a research programme to estimate nitrogen (N), phosphorus (P) and sediment event-based loads in the Moruya and Tuross River catchments of the New South Wales south coast. The research programme is designed within the context of an integrated catchment modelling framework (CatchMODS), to assess relative contributions from diffuse sources of nutrient and sediment export loads, and provide information for catchment management. In particular, the relative potential risk to water quality from dairying in the Eurobodalla region is being evaluated using a farm-scale nutrient budget approach.

Predominant land uses in the Moruya and Tuross River catchments are conservation and production forests, national parks, cattle grazing, and dairy production. There is little information on the quality of water entering the catchment estuaries, particularly during storm events when the majority of sediment and nutrients is transported to estuaries. The use of catchment models is commonly required to assist catchment managers to investigate water quality impacts at a catchment scale due to cost restrictions and data availability. To assess nutrient and sediment loads and enable management to achieve sustainable practices, the CatchMODS model is linked with a field-based data collection programme including water quality sampling to estimate suspended sediment, and total and dissolved nutrient loads on an event basis.

Potential sources of nutrients in the catchments are likely to include diffuse forest and agricultural inputs and gully erosion. Diffuse source pastoral agriculture has been linked to decreases in water quality and recreational use of surface waters.

To assess the potential impact of dairying, an evaluation of nutrient inputs and outputs, including leaching/runoff losses using a nutrient budget approach for a typical dairy farm in the Eurobodalla region, was undertaken. The Overseer® nutrient budget model was used. Farms were divided into relatively homogeneous management areas, namely irrigated-block, non-irrigated and effluent-application areas for use in the model. The model produces nutrient budget inputs and outputs for a range of nutrients for the farm as a whole and for each individual management block.

Initial results in this paper indicate N fertiliser usage on the dairy farms in this region is relatively low. Results indicate whole-farm long-term dairy farm leaching losses were 11 kg N/ha/year, which are considered low relative to other published studies. The overall whole-farm long-term leaching/runoff losses for P were estimated at 1.4 kg P/ha/year. Predicted whole-farm N concentration in drainage water at current average fertiliser usage is 3 ppm. This concentration is less than the guideline maximum for drinking water, although environmental acceptability depends on the sensitivity of receiving waters. In contrast, the simulated drainage N concentrations are greater than the guideline for lowland rivers in south-east Australia. Further evaluation of soil information, nutrient management and subsequent implications for water quality in the catchments as a whole is being investigated.

## INTRODUCTION

Nitrogen (N) and phosphorus (P) are important nutrients underpinning the functioning of many ecosystem processes. However, these nutrients can be lost from catchments via natural or anthropogenic processes. Eutrophication can occur, with problems such as algal blooms resulting in changes in the composition and species abundance and limitations on the use of groundwater for drinking and recreational use (McDowell *et al.* 2004). Recent studies show the importance of dissolved P losses to waterways particularly under dairying (Nash and Murdoch 1997) and dryland dairy cattle-grazed pasture (Cornish *et al.* 2002). The sources and forms of P vary depending on the characteristics and farming practices in a catchment.

The use of catchment-scale models is commonly required to investigate water quality impacts. Models can assist catchment managers to evaluate the likely impacts of changes in land use and management on the long term nutrient export status of catchments. Integrated catchment models have been developed such as the hydrological-based model CatchMODS (Newham *et al.* 2004). Currently, the CatchMODS model includes total sediment loads from overland flow hillslope-erosion processes using USLE, and sediment losses from gully and stream bank erosion.

To improve our understanding of nutrient inputs to streams, the contribution from intensive agriculture in Australia needs to be better quantified. Nutrient budget models have been developed and used in New Zealand to assess the likely N and P and other nutrient losses on a farm basis. Nutrient budget models can improve nutrient management on-farm and highlight potential environmental impacts from runoff and leaching (Wheeler *et al.* 2004). Our approach is to quantify likely N and P losses under dairying using a nutrient budget approach, which will be used, elsewhere, to compare with other land uses within the remainder of the catchment using CatchMODS.

In this paper, we present a framework to assess relative contributions from diffuse sources of nutrients and sediment export loads in the Tuross and Moruya catchments of New South Wales, to provide a tool and information for catchment management. We present an approach to quantify N and P losses under dairying and results using the nutrient budgeting package Overseer® nutrient budgets 2.

## CATCHMENT CARACTERISTICS

The Moruya and Tuross River catchments are located adjacent to one another approximately 300 km south of Sydney. The catchments are almost wholly located in the Eurobodalla Shire of NSW. The areas of the Moruya and Tuross catchments are approximately 1600 and 1850 $km^2$, respectively. Both catchments have similar features with approximately 10% flat coastal plain, 30% undulating and 60% rugged terrain. West of the coastal strip is a steep escarpment with elevations >1000 m. The catchments are predominantly native forest or national park in rugged terrain, while the cleared, flat or undulating coastal land surrounding the rivers and estuaries is used for agriculture, particularly beef cattle grazing. Dairy production in the Tuross catchment is predominant on moderately sloping land and floodplains. In both the Moruya and Tuross estuaries, oyster farming, recreation and tourism are important to the local economy. The Moruya estuary has a permanently open ocean entrance. In contrast the Tuross estuary has a complex array of lakes and channels formed behind a coastal sand barrier. With some exceptions, water quality is generally good, but this assessment is based on limited data with little information on the quality of water entering the estuaries during storm events. The long-term annual average rainfall in coastal areas of the catchments is approximately 1000 mm.

## MODELLING NUTRIENT INPUTS

### Overview of CatchMODS model

CatchMODS (Catchment Scale Management Of Diffuse Sources model) is an integrated modelling framework designed to simulate and assess catchment scale land management and thus reduce nutrient and sediment delivery to waterways (Newham *et al.* 2004).

The model structure integrates hydrologic, sediment and nutrient export models. Economic assessment of management options is also a feature which is important given that economic and social assessment are increasingly required in modelling frameworks. The modelling framework is designed to allow identification of priority subcatchments for management intervention. Although riparian revegetation and gully management is modelled, management simulation of riparian buffer zones is not.

Pollutant modelling in CatchMODS is lumped at combined stream reach and subcatchment units (Newham *et al.* 2004). Pollutants are routed between these lumped units to enable users to explore effects of management changes implemented in upstream subcatchments. The sediment submodel is based on the SedNet model (Prosser *et al.* 2001). This component includes estimation of gully, hillslope and stream bank erosion sources. Several enhancements to the SedNet-based sediment submodel have been implemented to improve sediment flux predictions, including: (i) estimating erosion rates and gully dimensions based on severity classes; (ii) improving the quality of spatial data inputs; and (iii) removing the historic dependence of the model for estimating source and transport processes.

The hydrologic sub model used is based on the IHACRES rainfall-runoff model (Jakeman and Hornberger 1993). The more recent catchment-moisture deficit version of the model with its low level of complexity reliably reproduces measured hydrographs and is therefore useful for applications in data-sparse catchments (Croke and Jakeman 2004).

The nutrient modelling component simulates three sources of N, namely sediment associated, groundwater associated and point source inputs. Nitrogen losses in stream reaches are estimated by an exponential decay using channel area, although the authors note this requires further testing (Newham *et al.* 2004). Total phosphorus export is estimated directly from modelled suspended sediment load, based on the assumption that P is transported on sediment particles (Newham *et al.* 2004). However, this type of relationship is likely to be different in intensively farmed catchments.

CatchMODS is likely to underestimate nutrient losses from intensively farmed land given the reliance on erosion sub-models. Therefore, as part of this overall study, we include a nutrient budget approach to assess likely N and P losses from dairy farming land. We will then assess the contribution of nutrients from the upper catchment and losses from non-intensively farmed areas using CatchMODS to determine the relative contributions to loads in the Tuross catchment. Comparisons with CatchMODS will be presented elsewhere. Next, we briefly discuss field calibration and testing of CatchMODS using an event-based water monitoring program.

**Event-based water quality monitoring**

This section briefly outlines an event-based water quality monitoring program, designed to enable nutrient and sediment load estimation, calibration and testing of the CatchMODS model. Single high-intensity storm events are often responsible for high percentages of nutrient and sediment loads. Consequently, accurate estimation of loads requires sampling under rainfall event conditions. Water monitoring sites were selected at Dept. of Planning, Infrastructure and Resources stream gauges at the lower Deua and Tuross Rivers. These sites are near Shire Council intakes for town drinking water. Stream gauge river flow history and current flow data was available. Given the recent drought, detailed methodology and results from event-based loads will be presented elsewhere.

**Nutrient cycling under dairy farming**

In this section, we describe an approach to assess the likely nutrient losses on a farm basis under dairy farming in the Eurobodalla Shire using a nutrient budget model approach. Nutrient budget models can improve nutrient management on-farm and can highlight potential environmental impacts from runoff and leaching. Our aim is to quantify the likely N and P losses from dairying, and the potential impact on water quality. Another aim is to evaluate the relative nutrient losses with those predicted for the remaining land uses of the catchments. The effects of land use intensification or management changes can also be evaluated.

The Overseer® nutrient budgets 2 model (Wheeler *et al.* 2004), developed for New Zealand agricultural systems was selected because of its strengths in modelling aspects of farm nutrient and effluent management and leaching and because of the similarities in dairy production systems between the two countries. There are few Australian nutrient budgeting software tools available, particularly for N. Overseer® has been shown to work quite well in Victoria, Australia (R Eckard pers com).

The model takes account of nutrient (N, P, K, S, Ca, Mg, Na) inputs and outputs such as atmospheric deposition (eg from clover), irrigation, nutrient content in supplements taken onto or off the farm, farm produce leaving the farm, transfers of nutrients onto races and via dairy effluent disposal management, and likely soil processes. This model is based on an annual time step estimating annual inputs and outputs of nutrients, and ignores year-to-year variability due to climate. The program uses climate, soil P and other soil information, farm input and management information. Research into nutrient cycling and losses from application of dairy effluent has been carried out in New Zealand and incorporated into the model. In contrast, there is little such published information available in Australia.

Information for the model on farm management, irrigation and fertiliser use, feed supplements purchased and usage, milk production, and dairy effluent management was collected during discussions with dairy farmers in the Tuross region. Soil samples were also collected from appropriately managed blocks to assess soil fertility, and pasture type and clover levels were noted. Dairy farms were divided into relatively homogeneous management areas, namely irrigated-block, dry-block (non-irrigated) and effluent-application areas for use in the model. The model produces nutrient budget inputs and outputs for a range of nutrients for the farm as a whole and for each individual management block.

Relationships were also developed to determine the effect of N application rates on the irrigated block on the changes in N leaching/runoff, atmospheric inputs and outputs and concentrations in drainage water, for the typical Eurobodalla dairy farm. Application rates above and below current usage were used. The irrigated block was chosen, as it is most likely to receive N applications. Consequent increases in pasture and hence milk production were therefore determined by either simulating (i) increases in per cow production, or (ii) increases in cow numbers.

## RESULTS

This section presents initial results for N and P inputs and losses from a typical dairy farm in the Eurobodalla Shire using the nutrient budget model. The initial results presented here were based on an average farm (230 ha) with a stocking rate of 1.4 cows/ha, producing 870 kg milksolids/ha, dairy effluent sprayed onto land (20 ha), 40% of the farm spray-irrigated (90 ha irrigated block), and 120 ha dry-land.

The nutrient budget for N and P for the "whole farm" and appropriately managed blocks are shown in Tables 1 and 2, respectively. Large quantities of N and P and other nutrients were added through purchased grain and feed supplements, with fertiliser and clover N fixation also important. As would be expected, inputs and losses were greater for the irrigated and effluent application areas (effluent block not shown) relative to un-irrigated (dry-block) areas. For example, average annual inputs of effluent N and P to the effluent application area were 250 kg/ha and 46 kg/ha, respectively. Annual N leaching losses from the effluent application area were 17 kg N/ha. The overall whole-farm long-term leaching/runoff losses were estimated at 11 kg N/ha and 1.4 kg P/ha per annum.

**Table 1.** Average dairy farm nutrient budget for nitrogen (kg/ha/yr)

| | Whole farm | Irrigated block | Dry-block |
|---|---|---|---|
| Inputs | | | |
| Fertiliser | 32 | 71 | 8 |
| Effluent | 0 | 0 | 0 |
| Atmospheric | 36 | 61 | 22 |
| Irrigation | 0 | 1 | 0 |
| Slow release | 0 | 0 | 0 |
| Supplements | 64 | 70 | 65 |
| Outputs | | | |
| Farm product | 67 | 70 | 67 |
| Transfer | 0 | 35 | 23 |
| Atmospheric | 26 | 34 | 12 |
| Leaching/runoff | 11 | 18 | 5 |
| Immobilisation | 48 | 47 | 29 |
| Inorganic soil pool change | -20 | 0 | -38 |
| Drainage conc'n (ppm N) | 3 | 5 | 2 |

Simulated inputs and outputs for the scenario where increased fertiliser N was used to increase per cow production (scenario i) is shown for the irrigated block in Figure 1, and for the whole-farm in Figure 2. Differences in leaching between this scenario and that which assumed an increase in cow numbers (scenario ii) were small (data not shown). Generally, scenario (i), without an increase in stock numbers, leached 6–9% less than scenario (ii). The simulation results clearly show increased N leaching/runoff, atmospheric outputs and concentrations in drainage with increased rates of N application to the irrigated block. However, overall losses from the whole-farm (Figure 2) are less than for irrigated block losses (Figure 1).

**Table 2.** Average dairy farm nutrient budget for phosphorus (kg/ha/yr)

| | Whole farm | Irrigated block | Dry-block |
|---|---|---|---|
| Inputs | | | |
| Fertiliser | 31 | 39 | 29 |
| Effluent | 0 | 0 | 0 |
| Atmospheric | 0 | 0 | 0 |
| Irrigation | 0 | 0 | 0 |
| Slow release | 3 | 3 | 3 |
| Supplements | 16 | 17 | 16 |
| Outputs | | | |
| Farm product | 12 | 12 | 11 |
| Transfer | 0 | 5 | 4 |
| Atmospheric | 0 | 0 | 0 |
| Leaching/runoff | 1.4 | 1.0 | 1.3 |
| Immobilisation | 21 | 18 | 21 |
| Inorganic soil pool change | 16 | 24 | 10 |

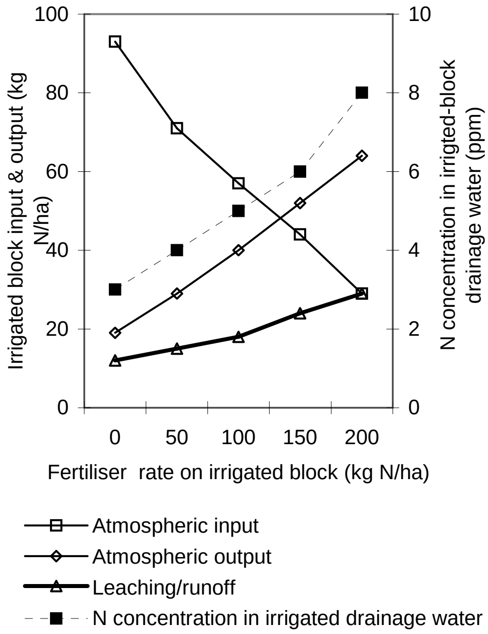


**Figure 1.** Predicted changes in atmospheric N inputs and outputs, leaching and N concentration in drainage water where N fertiliser is used to increase per cow production on the irrigated block (scenario i).

## DISCUSSION

The nutrient budget shows the main inputs of nutrients to a typical Eurobodalla dairy farm through the use of feed supplements (particularly grain), fertiliser and clover N fixation. In an "average" year overall farm N leaching/runoff losses are considered low relative to other published studies. N fertiliser is predominantly used on irrigated areas compared with non-irrigated dry-land areas. Our predictions of N leaching/runoff losses presented here are comparable with or less than the few studies reported in Australia (Eckard *et al.* 2004; Pakrou and Dillon 2000), and less than New Zealand (Ledgard *et al.* 1998; Monaghan *et al.* 2005). Our predicted losses were 11 kg N/ha/yr and 18 kg N/ha/yr for the whole farm and irrigated areas, respectively, and are in the order of losses found by Eckard *et al.* (2004) in Victoria. For example, when similar rainfall and soil drainage to our average farm model occurred in the study of Eckard *et al.* (2004), our results were similar to that study's zero-N treatment load in drainage of 14.6 kg N/ha (Eckard *et al*. range 3.7–14.6 kg N/ha depending on drainage). Similarly, our predicted N losses were lower than reported by Eckard *et al.* (2004) in their high drainage year (22 kg N/ha) for their 200 kg N/ha urea treatment. The generally lower average N leaching losses in our study than reported by Eckard *et al.* (2004) and Monaghan *et al.* (2005) may also be attributed to lower cows per hectare, therefore contributing to lower urine-induced losses (Silva *et al.* 1999).

Losses for zero-N and 200 kg N/ha urea treatments shown by Eckard *et al.* (2004) were substantially lower in lower drainage years (4–8 kg N/ha). Not surprisingly, it follows that leaching losses in the Eurobodalla are also likely to be reduced in drier years, although we have evaluated losses based on long-term predictions. Similarly, accumulation of soil nitrate in low drainage years is likely to contribute to greater losses in subsequent higher drainage years (Eckard *et al.* 2004). N-fixation inputs by clover in our study were also much lower than in other studies (Pakrou and Dillon 2000), quite likely due to kikuyu dominant pastures in the dryland blocks. Additionally, combined atmospheric losses (i.e., ammonia volatilisation and denitrification) and leaching losses for N were also lower than reported by Pakrou and Dillon (2000).

Predicted overall farm P losses (1.4 kg P/ha) were also considered low compared with losses of 1.9–2.5 kg P/ha/yr for an unfertilized dryland coastal NSW dairy (Cornish *et al.* 2002) and much lower than losses under dairying in the Hawkesbury area reported by Baginska *et al.* (1998). However, P loss in our study on the effluent application area (3.6 kg P/ha/yr), although a small area of the farm, was associated with greater P inputs and average soil Olsen P levels (70 mg/kg) than irrigated soil (Olsen P 29 mg/kg). Table 2 suggests a potential surplus of 10–24 kg P/ha/year (soil inorganic change). Such a potential surplus may result in increased soil P levels. The potential for changes in soil P levels and associated losses to waterways is being further evaluated. Research indicates overland flow P concentrations can increase with an increase in soil P levels (McDowell *et al.* 2004).

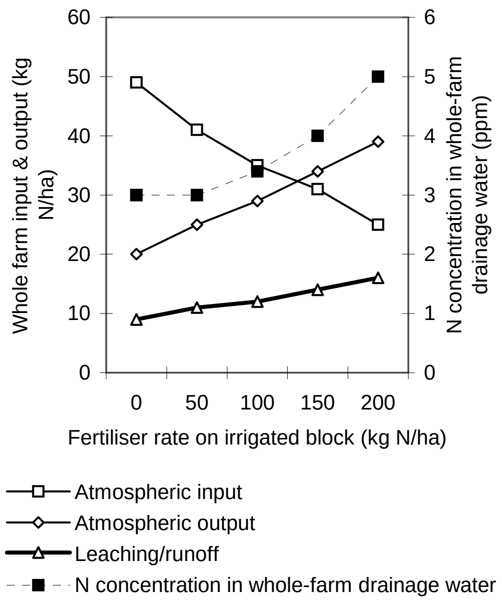


**Figure 2**. Predicted whole-farm changes in atmospheric N inputs and outputs, leaching and N concentration in drainage water where N fertiliser is used to increase per cow production on irrigated block only (scenario i).

Most water quality guidelines focus on limiting nitrate concentrations, but the quantity entering a water body is also important (Eckard *et al.* 2004). Our results consider the overall inputs and outputs from a typical dairy farm in the region. This work will be useful to compare with work being undertaken in other parts of the study to assess the relative contribution of nutrients from the upper catchment and non-intensively farmed areas using CatchMODS. Where possible, better integration of published data on land management, sediment, total and soluble nutrients into simple to use integrated catchment models is needed, particularly for assessing riparian management and losses. There is also a need to apply diffuse pollution models to other catchments particularly freshwater and estuarine systems, and to keep models simple and user-friendly, as data-hungry process-based models are often not suitable for end-users (Heathwaite 2003).

Although rates of up to 200 kg N/ha were simulated in Figures 1 and 2, it should be emphasised that average current N fertiliser usage in this study is 71 kg N/ha on irrigated land, with an overall farm average of 32 kg N/ha Table 1), notably lower than our highest simulated N rate. The whole-farm drainage water N concentration at current fertiliser usage is simulated to be 3 ppm (Table 1 and Figure 2). Simulated N concentrations in drainage water are less than 11 ppm, the recommended maximum for drinking water. However, environmental acceptability depends on the sensitivity of the estuaries. In contrast, the simulated drainage concentrations, even at low N application, are greater than the guideline for slightly disturbed lowland rivers in south-east Australia (ANZECC 2000).

As previously mentioned, Overseer® has been shown to work well in Victoria. However, further long-term validation under Australian conditions would be useful, but is beyond the scope of this project. In general, our results indicate N fertiliser usage on the dairy farms in this region is relatively low. Our approach has also been useful to quantify losses for management types. Our simulations indicate relatively low N leaching/runoff losses per hectare from dairying occurring long-term, relative to other published studies.

## CONCLUSIONS

Our overall approach is being undertaken to assess nutrient and sediment event-based loads from a catchment perspective, as there have been no published studies evaluating N, P and sediment loads especially during storm-flow, in these catchments. Initial nutrient budget results to estimate N and P losses from intensive farming indicate N fertiliser usage from a typical dairy farm in the region is considered low. Predicted long-tem leaching/runoff losses per hectare are considered low relative to other published studies. Further evaluation of soil information, nutrient management and subsequent implications for water quality within the catchments is being undertaken.

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