final report

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Making Better Fertiliser Decisions for Grazed Pastures in Australia

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Making Better Fertiliser Decisions for Grazed Pastures in Australia

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Final Report
June 2006

Victoria
The Place To Be

The Better Fertiliser Decisions project is supported by :

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EXECUTIVE SUMMARY

Fertilisers containing N, P, K and S will continue to be a key requirement for the Australian grazing industries. However, increased community concerns about excess nutrients in water and the atmosphere means that farmers and service providers need to have access to, and use, the best possible information regarding optimum nutrient management practices for environmental as well as productivity benefits. A more tailored approach to nutrient management, based on the best available information for soil test targets and a greater understanding of nutrient loss processes and pathways, will lead to greater nutrition conversion efficiencies on farm and reduce excess nutrients in the environment.

The 'Better Fertiliser Decisions' project has been funded for 3 years and commenced in June 2003. The principal objectives of the project were to (i) provide regionally specific and scientifically validated fertiliser-pasture production responses for various pasture types, climatic zones and soil types, (ii) to better define fertiliser management practices that account for nutrient loss processes and pathways, and (iii) integrate production and environmental information into materials and tools that can assist industry and government networks including fertiliser company advisers, environmental agencies, consultants, extension officers and farmers.

The project has delivered the most comprehensive collation and summary of soil test calibration studies for pasture production ever undertaken in Australia, and probably internationally, as well as a new 'Farm Nutrient Loss Index' to assist farmers and advisors in reducing nutrient losses from the farm.

Improved soil test calibrations

The collation of soil test calibration studies resulted in more than 4500 experimental site years of data being gathered from all states of Australia. These data have been standardised and organised into a relational database. The database has allowed information from many different experiments to be combined and re-analysed to develop improved soil test calibration equations. The data has also been used to identify regional and soil textural differences influencing soil test interpretation. The extensive collation, standardisation and statistical interpretation has resulted in a total of 118 new response relationships for all soil tests used (currently and historically) across Australia. These equations will form the basis of national standards for soil test interpretation by the Australian fertiliser industry and other advisors.

Farm Nutrient Loss Index

Unlike soil testing, there has been no comprehensive assessment tool that can be used by the grazing industry to specifically identify the temporal and spatial risks of nutrient movement from farms. The 'Farm Nutrient Loss Index' (FNLI) has utilised the best possible information regarding nutrient loss processes and pathways in the development of a decision support tool which predicts the risk of phosphorus and nitrogen loss due to land-use practices, soil types, landscape characteristics and climatic conditions. The FNLI has been designed as both an 'educational' tool and an 'advisory' tool to systematically assess and report on the relative risks of nutrient losses from different paddocks in pasture-based grazing systems.

A selection of people from 'educator' and 'service provider' groups has been actively engaged in the ongoing development of the FNLI. Technical workshops were held at nine locations throughout Australia and involved 92 nutrient management experts who provided input into the development of the FNLI. These workshops were supplemented with on-farm assessments using the FNLI as well as workshops with farmers to gather feedback on the utility and validity of the FNLI outcomes. After the FNLI was developed, the Index risk outcomes were validated against measured field data.

Partnerships

The strong partnerships developed with the fertiliser industry, grazing industries and government extension and research staff, and their involvement throughout the project, has ensured that products and tools developed throughout this project are consistent with the needs of the fertiliser industry and farmer advisors.

INTRODUCTION

The cost-price squeeze, intensification and market signals for higher quality and more uniform products have stimulated a significant rise in fertiliser use in the grazing industry of Australia over the past decade. However the efficiency of fertiliser use is often low (Peverill *et al.* 1999). For example, less than 10% of P applied in fertiliser may be utilised by the pasture, with the remainder largely accumulating in poorly available forms (Burkitt *et al.* 2004). Similarly, the use of N fertilisers can be highly inefficient. For example, annual N losses from dairy systems are estimated between 20 – 40 % of that applied in fertiliser (Eckard *et al.* 2003). In addition, for intensive grazing industries such as dairy production, the inputs of N and P (in fertilisers and purchased feed) can far exceed the off-farm export of these nutrients in farm products (Reuter 2001), leading to a build up of nutrients and risk of pollution of waterways. Nutrients that move off-farm from dairy, beef and sheep pastures can increase the risk of degradation of surface (Nash *et al.* 2000; Melland 2003) and ground waters (Di *et al.* 1998) through eutrophication, and the risk of greenhouse gas accumulation in the atmosphere through nitrous oxide emissions (Eckard *et al.* 2003).

Whilst there is relatively little regulation of farm nutrient management practice in Australia compared with Europe, USA and New Zealand, agricultural industry and government bodies are continually working towards triple bottom line sustainability (environmental, economic and social). For example, the Fertiliser Industry Federation of Australia is establishing an accreditation program (Fertcare®) for industry staff to set and maintain industry standards of environmental stewardship. Self-assessment approaches to documenting and improving environmental stewardship are also being adopted by individual industries, companies and landholders in response to foreseeable quality assurance and market access drivers for producers (Gourley and Ridley 2005). Research and development within the Australian grazing industries is focussed on developing realistic strategies to meet natural resource conditions and management targets set within state and federal government catchment management plans (Ewing 2003).

A key part of balancing production and environmental objectives in grazed pasture systems is the efficient use and careful management of nutrients (Gourley 2004). The ‘Making Better Fertiliser Decisions’ project was instigated to help inform farm nutrient management decisions made by sheep, beef and dairy farmers.

The projects aims were to

(i) provide regionally specific and scientifically validated fertiliser-pasture production responses for various seasonal, climatic and soil conditions,
(ii) identify landscape, soils and fertiliser management practices that impact on the environment, and

(iii) integrate the production and environmental information for key fertiliser stakeholders.

These aims are reflected in the three modules: Production, Environment, and Communication.

The Production module sought to use the considerable research into optimum application of N, P, K and S nutrient management that has already been undertaken for the Australian grazing industries through the collation, integration and statistical analysis of this information for inclusion in a national database.

The Environment module developed a practical framework to assess the potential for nutrient loss at a paddock scale, and road test the FNLI across regions nationally. The FNLI was developed to suit the range of input information available, for example farmer observations versus intensive sampling, and to consider the goals and priorities of a range of end users, in order to encourage uptake and adoption.

The Communication module produced awareness raising material and information on the project outputs. It maintained information flow to stakeholders on project operations.

This project provides the best available information for making environmentally responsible fertiliser recommendations, while additionally identifying key knowledge gaps requiring further research.

The *Making Better Fertiliser Decisions for Grazed Pastures in Australia* project has widespread national support from Dairy Australia, Meat and Livestock Australia, Land and Water Australia, the National Land and Water Resources Audit, the Fertiliser Industry Federation of Australia, Incitec-Pivot, CSBP, Hifert, Canpotex-Agrow, Impact Fertilisers, Department of Primary Industries Victoria, Agriculture WA, South Australian Research and Development Institute, NSW Agriculture, Department of Primary Industries Qld, Department of Natural Resrouces and Mines Qld, Tasmanian Institute of Agricultural Research, Department of Primary Industries Water and Environment and Environment Protection Authority Victoria.

PROJECT OBJECTIVES

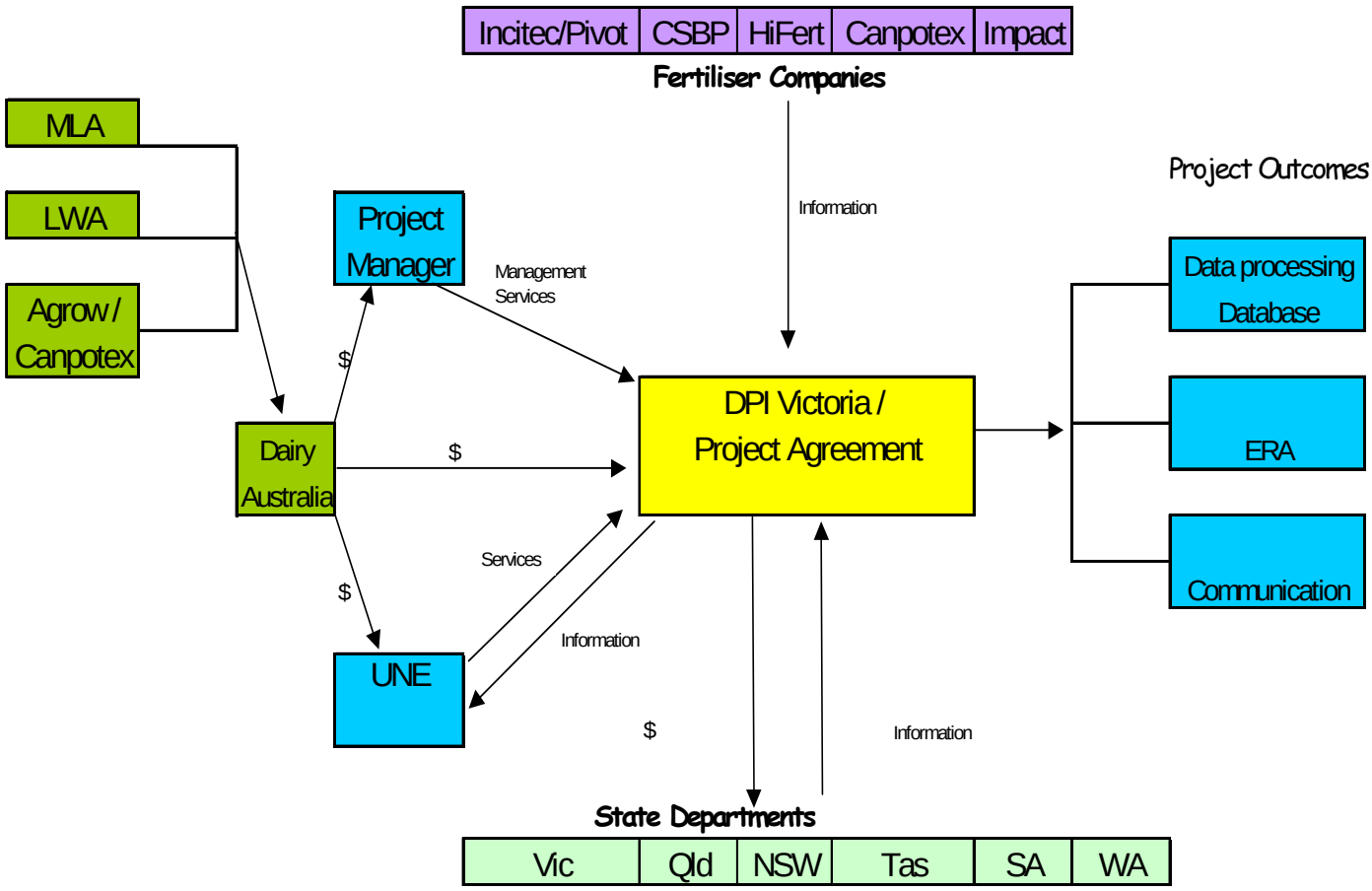
The project objectives were:

(i) To provide regionally specific relationships for soil test – pasture response functions for phosphorus, potassium, and sulphur fertilisers and pasture response functions for nitrogen fertiliser (and where possible animal production responses) from existing data for extensive and intensive pasture systems across Australia, through an interactive database.

(ii) To review and develop tools that identify landscape characteristics, soils and Farm Management Practises that contribute to impacts on the environment, and to integrate Environmental Risk Assessment and nutrient response functions.

(ii) To disseminate consistent and regionally specific nutrient response relationships and Environmental Risk Assessment tools to regional industry and government networks including fertiliser company advisers, consultants, extension officers and farmers to provide greater skills and confidence in fertiliser decision-making.

PROJECT STRUCTURE



PROJECT TEAM

Science Management Team

Ken Peverill	Project Manager
Cameron Gourley	Science Leader
Alice Melland	Agri-Environmental Scientist
Paul Strickland	Project Officer
Andrew Smith	Scientist – Environment Module
Chris O'Hara	Scientist – Environment Module
Ivor Awty	Senior Technical Officer – Production Module
Donna Gibson	Technical Officer – Production Module
Murray Hannah	Senior Biometrician

Project Steering Group

A Project Steering Committee was established to:

- Provide strategic oversight and advice regarding the project.
- Review progress at different stages of the project according to specified timelines, ensuring that the project remains relevant and valuable to all stakeholders.
- Identify any additional specialist technical input required.
- Communicate with the various stakeholders to promote political, regulatory, industry and community awareness and support and gather ideas that contribute to the strategic direction of the project.
- Identify any further funding opportunities that cover any budget shortfalls.
- Identify further opportunities for information transfer.

Membership includes representatives from the principal funding bodies, the fertiliser industry, and various State and Commonwealth agencies across Australia.

Nick Drew	FIFA and Chairperson
Cameron Allan	MLA
Tom Davison	Dairy Australia
Nigel Bodinnar	Incitec/Pivot
Brendan Edgar	LWA
Peter Flavel	HiFert
Phil Moody	Qld
Peter Orchard	NSW
Digby Short	CSBP
Nigel Wilhelm	SA
David Windsor / Greg Sawyer	WA
Blair Wood	NLWRA
Roger Strong	Beef Producer representative

National Network

A team of researchers, extension officers and fertiliser industry representatives (the National Network, NN) was established to provide high level scientific expertise and practical industry knowledge from across Australia. This included providing advice and, where possible, data as input to both the productivity response database and

the environmental risk assessment tools. Members included representatives from state agriculture departments, universities, CSIRO, and fertiliser companies.

Fertiliser Industry Representatives on National Network

Incitec-Pivot: Jeff Kraak (D), Garry Kuhn (E)
CSBP: Ed Pol(D), Digby Short (D)
HiFert: Peter Flavel (D), Andrew Speirs (D)
Canpotex: Jonnie White (D)
Impact Fertilisers: David Orr (D)

State Representatives on National Network

Vic: Malcolm McCaskill (*DE), Fiona Robertson (E) Richard Eckard (DE), David Nash (E), QJ Wang (E), Colin Waters (C), Joe Jacobs (D), Peter Sale (D), Aravind Surapenini (E), Tim Johnston (E); Doug Newton (DE);
NSW: Peter Cornish (E), Mark Conyers (*D), Graham Crocker (D), Sean Murphy (E);
WA: Mike Bolland (D*), David Weaver (E), Tresslyn Walsley (E);
Qld: Phil Moody (*DE), Kevin Lowe (*D), David Freebairn (E), Rob Chattaway (C);
Tas: Lucy Burkitt (*DE), Phil Smethurst (E), Leigh Sparrow (DE);
SA: Nigel Fleming (DE), Dale Lewis (D), Doug Reuter (D) and Denis Elliott (D), Jim Cox (E), John Hutson (E), Warwick Dougherty (E).
ACT: Richard Simpson (D).

D = Production module, E = Environment module, C = Communication module
* designates that this person is a key State provider for this module.

Industry Working Group

The Project Steering Committee (PSG) established an Industry Working Group comprised of PSG representatives from the national fertiliser industry to provide specific feedback to the science team on the development of project outputs, especially the production database and FNLI.

Participants at the May 2004 National Network meeting in Melbourne

PROJECT MODULES: PROCESSES AND OUTCOMES

Production Module

On-farm management of fertiliser is of major economic significance to the Australian grazing industries, based on expenditure on fertiliser and the higher farm productivity enabled by fertiliser use. Better adoption and application of tools like soil testing can substantially improve nutrient use efficiency. To make soil testing useful for farmers, interpretation of soil test data needs to be based on the best available information.

The objectives of the Production Module were:

(i) To develop standard and regionally specific soil test – pasture response functions for phosphorus, potassium and sulphur fertilisers and pasture response functions for nitrogen fertiliser across Australia using existing data
(ii) To develop a framework for consistent interpretation of soil tests from (both) a productivity (and environmental) perspective
(iii) To identify weaknesses in the datasets available and identify specific research to fill these gaps in knowledge

Data Collation

Initial planning with the National Network to establish guiding principles for data collation.

Historically there have been many reviews that have compiled fertiliser-pasture response data in different regions of Australia. In the initial planning phase with the Science Management Team, it was resolved that this project would attempt to capture datasets from previous reviews, published papers, departmental reports and where appropriate and available, unpublished material.

These datasets would be integrated to derive the most appropriate response relationships available for the grazing industries in Australia. The response relationships derived from this pool of data would then be interpreted by the Relational Database Unit and the biometrician at the University of New England, before being sent back for review by the NN and where appropriate by independent scientists.

The team members of the Production Module met in July 2003 to develop:

- A vision for the national data repository for pasture responses to N, P, K and S that provide a trusted, credible and quality-assured database with referenced links to experiments.
- A framework with essential criteria for acceptance of field response data to applied nutrients (N, P, K and S).
- A readily understood and reproducible format for submission of data for statistical assessment and processing into the national database.

Subsequently, at the first National Network (NN) Team workshop that was held in Melbourne during August 2003, the NN team members endorsed the vision and discussed the guidelines in detail, leading to further refinements.

Collation and submission of datasets

Using the agreed criteria for acceptance of field response data to applied nutrients, nominated NN representatives from State Departments, CSIRO, universities and fertiliser companies agreed to focus initially on collating data that were readily accessible (such as published data from refereed journals and internal reports) and then to collate unpublished material. The aim was to progressively submit readily accessible data by October 2003. However, this timeline proved to be unrealistically optimistic owing to the amount, format and relative inaccessibility and complexity of the data records, some of which dated back more than 50 years. The receipt of the last datasets occurred in December 2005.

Ken Peverill and Jim Scott (UNE) organised a template, which was circulated to all NN members, in order to assist with data submission. The MS Excel template provided a standard format for all the field and laboratory data, and for supplementary site information such as soil description and classification, location, experimental design, soil sampling depth, other soil and plant tests, climatic data, animal measurements etc. Each template was also accompanied by a MS Word document that described the aims of the particular field trial, the nutrient application rates and form of applied nutrient, the number of replicates, the experimental design and the field methodology including the harvesting techniques used. NN members were to add additional information about the experimental rigour/site variability/trial outcomes within a covering email so that the merits of data sets could be considered. This huge quantity of complex data with highly variable quality meant that numerous problems / barriers were experienced. The examples below are simply examples of various types of problems that were regularly encountered. Examples of the types of data provided on the templates are provided in Figure 1.

Database Development

Architecture of database

Several attempts were required to finalise the architecture of the database in order to provide the necessary flexibility to cope with highly variable data inputs yet still provide an easy to operate environment that offered users the capacity to interrogate datasets through a range of portals ie. nutrient, region.

Quantity

Almost 200 datasets were submitted, most of which presented data from a number of experimental sites or commonly covering more than one (1) trial year or more than (1) nutrient under investigation.

Quality / formatting

Even though an Excel template was prepared and circulated to all contributors for use as a guide, the discipline required to format data unambiguously was commonly not achieved leaving the Production Module (PM) staff with the task of asking contributors numerous questions of clarification and even then formatting rigour and data clarity were ultimately achieved by the PM staff.

Complexity

Numerous datasets had multiple harvests while others only had one harvest or the composite dry matter yield from multiple harvests. This posed a major

problem of how to process such data but it was resolved that each harvest could be treated as a separate experiment. This actually increased the number of experimental trial years to a figure far in advance of those stated above. Further difficulties arose with trial designs that involve fertiliser treatments between harvests.

Variability

Confusion regularly occurred for the database officers with inconsistency in describing such parameters as a soil test result (eg. Colwell P, sodium bicarbonate extractable P, bicarbonate P etc.), choice of metric units (eg. t/ha or kg/ha and mm or cm) and fertiliser name and abbreviation.

Quality assurance

Large datasets may have hundreds and even thousands of rows of treatments across replicates, sites etc. and numerous columns of measured parameters. Manual checking mechanisms were time consuming in order to identify and subsequently check any apparently aberrant data entry. Even checking word documents that described the trials for meaning was arduous.

Resourcing

The Relational Database Officers at UNE were database specialists and were unfamiliar with many of the agronomic terms used and hence additional assistance with interpretation was essential. Ken Peverill and DPI agronomy staff assisted in the data entry process by reviewing submitted data and revising it to conform to a standard format.

Contracted role of UNE relating to the database and statistical analyses

Initially UNE constructed a complete user-interface database that provided a view of what was planned to become the final product. A skeleton database was constructed to facilitate discussion and interaction with the project team and for demonstration at the NN meetings.

The database was created to allow for the future storage of data from a wide range of sites' data using Microsoft Access. The UNE Relational Database Unit developed tools that ensured that all data could be quality assured and provide a tree view of the datasets as an intuitive interface for interrogating the data. They also incorporated within the database the preliminary statistical analyses performed on selected datasets by Dr Bob Murison (UNE Department of Mathematics, Statistics and Computing Science).

Owing to the sheer number and types of data files received, UNE was unable to include all of the data in the database within the two year contract period even though it employed an additional database officer in December 2004. As the volume of data files increased, a substantial amount of additional processing code was needed. When it became evident that the RDU could not include all data qualifiers if all of the datasets were to be included into a unified database structure, a reduced target of the best data was negotiated.

At the end of the contract period, the Project Steering Group decided against an extension of the contract because of the risk that UNE may not be able to deliver the additional outputs to fully populate the database within the time frame remaining. The assessment of risk was based primarily on UNE advice that due to internal University financial decisions continuation of the existing employment contracts for the database staff was not likely. However, at

handover to DPI Ellinbank, the RDU provided the current status of data processed together with appropriate documentation relating to the framework, QA / tracking and operation of the database in order to permit the remainder of the outstanding tasks within the project timeline.

Description of the magnitude of the datasets

Originally it was anticipated that an estimated 30 principal datasets would be collected from across all States of Australia and that these major contributions would commonly be quite data rich with most datasets including a number of trial sites. It was expected that these data would be used to generate the relative response vs. soil test curves. All other datasets (approx 200) that possessed key parameters (soil test, soil texture, location, pasture yield and nutrient applied including nil and a likely max yield) were only likely to have been used for validating the curves. However, after the datasets and the database was transferred to the DPI Ellinbank team of Ivor Awty, Donna Gibson and Murray Hannah (Biometrician) under the guidance of Ken Peverill and Cameron Gourley, it was resolved that all datasets that possessed the critical data parameters would be pooled together on a State wide basis for statistical analysis.

Since counting the number of datasets submitted gives no real perspective of the total of trial years of data submitted, it was found to be more meaningful to present the total number of nutrient site years and the number of nutrient site years for each nutrient as well as the total number of experiments. The total of nutrient site years is over 4500. This represents data from over 250 datasets submitted and processed for statistical analysis, while some 400 dataset files have been archived but not processed for statistical analysis.

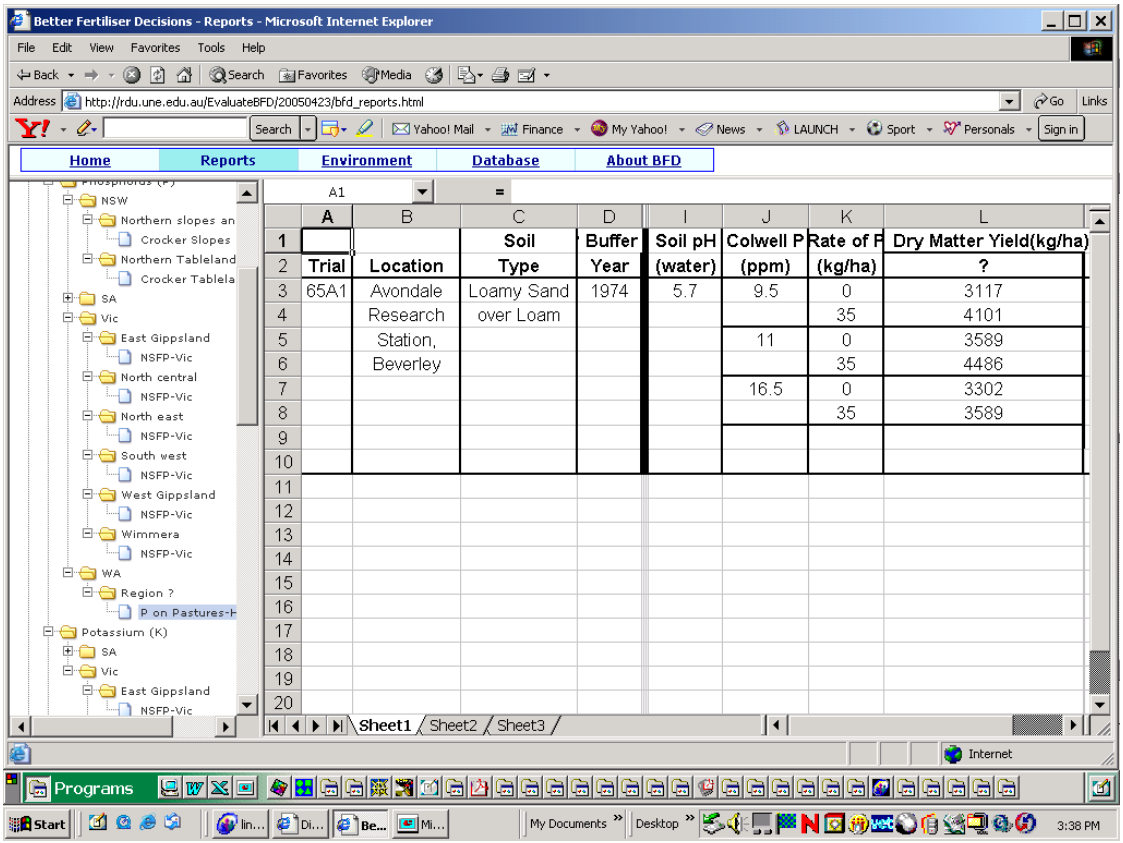
Changes to the initial templates and pooling of datasets

As described above, all datasets that met essential criteria (fertiliser rates including a nil and estimated rate for Y max, a soil test value prior to fertiliser being applied or from the nil plot, the soil texture and the location / region) were forwarded to Murray Hannah for statistical analyses and conversion into response relationship graphs. Prior to statistical analysis, all datasets were transformed into an agreed data transfer presentation (dtx) format and pooled together on a State wide basis.

Once each State wide dataset on the dtx transformed template had been prepared for P, K and S, they were returned to the various contributors within a State for checking that all of the datasets had been included, that no transfer errors from the original file had arisen, that no incorrect assumptions relating to soil test, soil texture, region etc. had occurred and that the datasets were appropriately titled.

Since nitrogen datasets do not include a soil test result for N, these files are generally processed into dtx presentation format but not statistically analysed. Such datasets are accessible for plotting yields against parameters such as nitrogen fertiliser rates using the flexigraph facility within the database.

If all the essential criteria are not met for a particular dataset, the data file cannot be statistically analysed but it is retained and accessible in an archival file within the database.



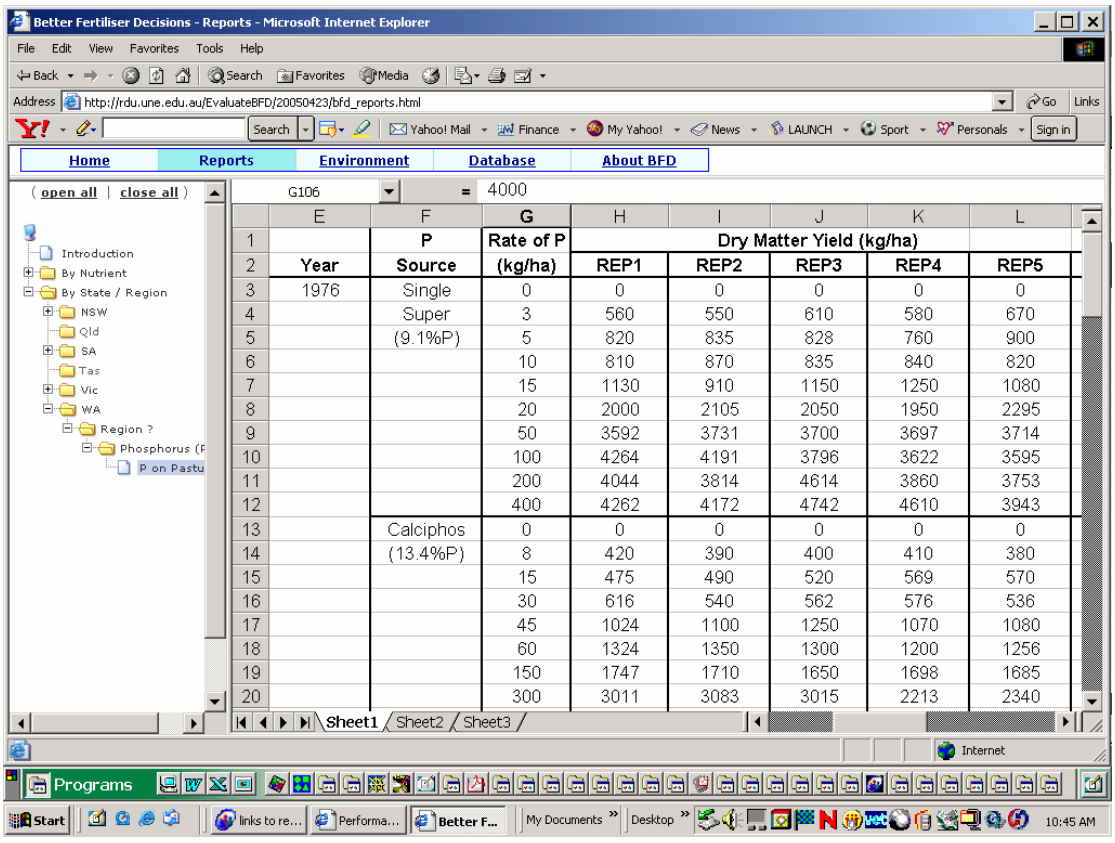


Figure 1: Examples of the types of submitted data sets used in the Better Fertiliser Decisions Relational Data base.

Statistical analyses of datasets

With the pooling of state wide datasets, rather than the original processing of the separate key (29) datasets, all previous statistical analyses became redundant.

For each dataset, Murray Hannah (biometrician) calculated the relative response (RR) for each trial site that has a known soil test value and then ploted a single point of RR and soil test for each trial. For example:

Relative response (rr) was calculated for phosphorus data as

$$rr = \frac{mx - mn}{mx}$$

where *mx* was the mean yield at the max rate of P applied, *mn* was the mean yield at the minimum (*i.e.* zero) rate of P applied.

This formula was used because it guaranteed a result whist maximizing stability (*i.e.* good precision). It is a conservative method in that it tends to underestimate actual rr in cases where an experiment has no “really large” P application. By “really large” we mean a rate that gives the effective maximum response.

The practical considerations were that:

a) Curve fitting may or may not converge (so the above avoids these numerical problems),
b) The curve parameter corresponding to *mx* (needed in the curve-based method for calculating rr) is a projection at applied P = ∞, and can and often does produce wild results, unless the data set is very good (see Ratkowsky, David A, Handbook of nonlinear regression models).
c) There were often insufficient data to even begin to fit a curve (e.g. with just 2 rates of P it is impossible to estimate a 3-parameter curve).

Interpretation of nutrient response curves

The large amounts of collated and standardised experimental data generated from field work undertaken in different states, regions and soil types, and spanning nearly seventy years, has been used to define new and better defined soil test – pasture response relationships.

Some users (eg. fertiliser companies, consultants and extension officers) and end users will require their data to be displayed at a regional level while others (eg. researchers) may wish to pool datasets to State wide or even National level unless there are obvious regional differences in the response curves. Commonly some regional data curves or soil textural curves lack enough points in order to plot a curve that does not display meaningless variability. In such cases, the user can combine datasets from adjacent or climatically like regions or directly refer to the curves for adjacent / like regions or alternatively rely upon the State wide curve. Similarly it will be possible to combine similar textural groups together to establish a more meaningful curve.

Response curves have therefore been created at a State and Regional scale for phosphorus, potassium and sulphur provided sufficient datasets were available. There are separate response curves for each P and S soil test used (eg. Olsen P, Colwell P, Bray P, Kerr and von Steiglitz P, or CPC S, KCl40 S,

MPC S) providing that adequate datasets exist for a particular soil test. For P and S, the various soil tests used generally cannot be inter-converted one to another even with the aid of a conversion factor. However, different potassium test procedures usually yield the same result when presented in units of mg/kg (eg. Colwell K, Skene K, Exchangeable K).

Discussions relating to the need for presenting curves at aggregated and disaggregated together with the mode of presentation of the tree structure and the ease and utility of operation of the database were refined following a number of suggestions arising from a November 2005 meeting of the Fertiliser Industry Working Group. Most of these suggested changes have been accepted and incorporated within the current working database.

Each State curve can be disaggregated into individual soil textural classifications provided that the datasets for any one textural grade is sufficient for fitting a curve. The textural classes chosen are: sands, sandy loams, sandy clay loams and clays. In contrast, each State wide dataset can be pooled together to create a National dataset for presentation as a response curve. The National dataset curve can also be disaggregated according to soil textural classes as described above.

Relative response curves generated through the utilisation of all available data in this nationwide study permits the user to determine a 'critical value', determined as the soil test level at a RR value of 0.05. In the simplest form, this critical value permits the establishment of a single value which can be useful to justify whether further fertiliser applications to increase the plant available nutrient status may be warranted. It should be noted that a properly defined fertiliser recommendation phase necessarily has to consider numerous additional factors such as the gross margin, cost of imported grain / hay, stocking rate, a farmer's financial state etc.

Table 1 provides a summary of the different agronomic soil fertility tests used across Australia and at a state and national level, the number of experimental site years of data collected and collated in the relational data base. The significance of this ability to collate and combine disparate data sets can be seen in the following examples, which includes the key soil tests used in Australia.

Table 1. The number of experimental site years of data collated for various soil tests across States and nationally.

State	OlsenP	ColwellP	Bray1P	Bray2P	LactateP	Fluoride P	Acid ExtractableP	Kerr & Von Stieglitz
Tasmainia	0	532	0	0	0	0	0	0
NSW	66	269	87	60	66	60	0	0
VIC	395	420	91	39	91	0	39	0
SA	70	548	30	0	0	0	0	0
WA	35	430	0	26	0	0	0	0
QLD	0	45	1	21	0	0	0	35
National	566	2244	209	146	157	60	39	35
	MorganP	**EgnerP**	**ColwellK**	**Skene K**	**Exch K**	**CPC S**	**KCl40 S**	**MCP S**
Tasmainia	0	0	512	0	0	0	0	0
NSW	0	0	128	0	114	83	24	0
VIC	91	91	277	104	94	167	0	89
SA	0	0	19	0	1	0	33	29
WA	0	0	164	26	0	0	1	0
QLD	0	0	10	0	9	11	0	7
National	91	91	1110	130	218	261	58	125

Colwell P

The Colwell soil test has become the most commonly used phosphorus soil test in Australia, in particular in WA, NSW and SA. Despite this, key questions relating to the interpretation of this soil test remain, such as our ability to differentiate critical Colwell P soil test levels across regions and soil types. The large amount of data collated through this Better Fertiliser Decision Project (Table 1; in the case of Colwell P more than 2244 experiment site years of data, which is nearly 50% of all collected soil test data) has now been combined at the national level, differentiated across the national level for different soil textural classes, differentiated at a state level and a regional level again across different textural classes.

Figure 2 and Figure 3 shows the totality of the nationally collated Colwell P data, the availability of data from different states and how this data can be differentiated between different soil texture classes.

The combined national data set was used to derive a single response relationship with a critical Colwell P value of 35 mg/kg. When the data was separated into different soil textural classes there were only very small differences in derived critical values, and no clear trend of increasing critical value with increasing clay content (Table 2). Sandy loams (critical value of 41 mg/kg) and Clay loams (critical value of 39 mg/kg), were perhaps the only exceptions, and these values are not substantially different from the critical value derived for the combined data set (Table 2). These results challenge the existing view that the critical Colwell P levels increase substantially with increasing soil clay content. Further work is required to differentiate soil textural classes within each State.

The possible combinations for Colwell P interpretation at a national, state, regional and textural grouping numbers 20 separate newly derived response relationships. These relationships are not presented in this final report and are available in the final relational database tool.

Table 2. Critical Colwell P soil test levels (mg/kg) and 95% confidence intervals for different soil textural classes derived from the nationally pooled data.

Category	*Critical value*	*Critical range*	*n*	r^2
National	35	34 -36	879	0.477
Volcanic clay	-	-	9	-
Clay	35	34 - 37	75	0.558
Clay loam	39	37 - 40	185	0.265
Sandy clay loam	41	38 - 43	39	0.351
Sandy loam	35	34 - 36	282	0.453
Sand	34	33 - 35	286	0.477

Olsen P

Olsen P is the second most commonly used soil phosphorus test in Australia and is the routine test used in Victoria. A total of 566 experimental site years of data have been collected and collated to derive national Olsen P soil test calibration, however 395 of these come from Victoria (Table 1). Figure 3 and Figure 4 shows the totality of the nationally collated Olsen P data, the

availability of data from different states and how this data can be differentiated between different soil texture classes.

The combined national data set was used to derive a response relationship with a critical Olsen P value of 24.8 mg/kg, though the r squared value overall was only 0.199. When the data was differentiated across soil textural classes, different critical Olsen P values were determined for all soil textural groups except volcanic clays. Although there was not a clear trend of increasing critical value with increasing clay content (Table 4), the 'Sand' textural class in particular had a much lower critical Olsen P value (14.1 mg/kg), while Sandy loams, sandy clay loams, and clays had similar critical values (ranging between 21.7 and 28.1). At the other extreme, Clay loams had critical levels of 35.8, though the critical range was large and the r^2 value only 0.085 (Table 3). These results also challenge the current recommendation that a standard critical value be used for Olsen P, irrespective of the soil texture, as these results suggest that a different critical value should be proposed for sands while a common critical value can be used across all other soil textural classes. Further work is required to differentiate soil textural classes within each State.

Table 3. Critical Olsen P soil test levels (mg/kg) and 95% confidence intervals for different soil textural classes derived from the nationally pooled data.

Category	*Critical value*	*Critical range*	*n*	r^2
National	24.8	20.1 - 29.5	305	0.199
Volcanic clay	n/a		15	
Clay	28.1	20.6 - 35.5	41	0.504
Clay loam	35.8	13.2 - 58.4	101	0.085
Sandy clay loam	24.5	8.2 - 40.7	25	0.093
Sandy loam	21.7	14.2 - 29.3	80	0.209
Sand	14.1	10.1 - 18.1	31	0.38

N/A not able to derive response relationship

Other soil phosphorus tests

A range of additional soil phosphorus tests have been used in Australia including Bray1 (209 experimental site years) and Bray2 (146 experimental site years), lactate (157 experimental site years), fluoride (60 experimental site years), and to a lesser extent Acid extractable (39 experimental site years), Morgan P (91 experimental site years) and Egner P (91 experimental site years). Of note is the Kerr and Von Stieglitz test (35 experimental site years) used in Queensland. This test correlates well with results from Colwell P tests and a conversion factor of 0.85 has been used to increase the amount of Colwell P data available for Queensland. No such correlations have been determined for any other lesser used tests and separate calibration curves for these historical and no-longer used soil tests have not been generated to date.

Colwell K, Skene K and Exchangeable K

Despite the fact that different soil tests, namely Colwell K, Skene K and Exchangeable K have all been routinely used to measure plant available

potassium, they extract similar levels of soil K and are strongly correlated. Colwell K has been the more heavily used soil K test with 1110 experimental site years while Skene K had 130, and Exchangeable K had 218, making it a total if 1458. Therefore Skene K (conversion factor Colwell K: Skene K, 1:1) and Exchangeable K (conversion factor Colwell K: Exchangeable K, 1:390) have all been standardised to relative Colwell K values and used to derive relationships for soil test K at the national, state, regional and soil textural levels.

Figure 6 and Figure 7 shows the totality of the nationally collated (actual or calculated) Colwell K data and the same data, differentiated between different soil texture classes.

Most of the data came from Victoria (335 experimental site years), while Tasmania provided (60 experimental site years) and WA (45 experimental site years) also provided data. There were very few, if any data provided from the remaining states (NSW 4 experimental site years, SA 1 experimental site year, and Qld 0 experimental site years).

The combined national potassium data set was used to derive a response relationship with a critical Colwell K value of 169 mg/kg. When the data was differentiated across soil textural classes, there were only small differences in critical Colwell K values determined for all soil textural groups, ranging from 160 – 173 mg/kg (Table 4). No experiment data was available for volcanic clays, and the small number of sites on clay soil did not allow a response relationship to be determined (Table 4). These results suggest that the current approach of recommending different critical Colwell K values for different soil textures is not warranted and that a standard critical value be used for Colwell K, irrespective of the soil texture.

Table 4. Critical Colwell K soil test levels (mg/kg) and 95% confidence intervals for different soil textural classes derived from the nationally pooled data.

Category	*Critical value*	*Critical range (p<0.05)*	*n*	*r^2*
National	169	151 - 186	466	0.51
Volcanic clay	N/A	-	0	-
Clay	N/A	-	5	-
Clay loam	173	149 - 198	194	0.47
Sandy clay loam	164	113 - 215	75	0.29
Sandy loam	165	130 - 200	122	0.47
Sand	160	110 - 209	50	0.47

N/A not able to derive response relationship

MCP, CPC and KCl40 sulphur tests

The development of a soil sulphur test that reflects the availability of plant available S has been a difficult challenge due to the nature of sulphur and it's transformations in soil. The sulphur tests used in Australia include MCP S, KPC S and KCl40 test. These tests have not had the wide spread calibration or use that the phosphorus and potassium tests have. In total 444 individual site years of experimental field data were collated across all states of Australia (Table 1). Of this total 261 sets included data relating to the CPC sulphur test,

125 related to the MCP sulphur test and only 58 related to the KCl40 test. This is a surprising result considering that the KCl40 test has become the national standard soil sulphur test across Australia. Furthermore the calibration of the KCl40 sulphur test is limited to work undertaken in SA (33 site years) and the central tablelands of NSW (24 site years) with 1 site in WA.

Figure 8 shows the relationship between CPC S soil test levels and relative response values for Victoria, at a state and a regional level. Figure 9 shows the relationship between KCl40 S soil test levels and relative response values for NSW, at a state and a regional level. Note that the calibration of the KCL 40 S test in NSW has been limited to only the Central tablelands (Figure 9).

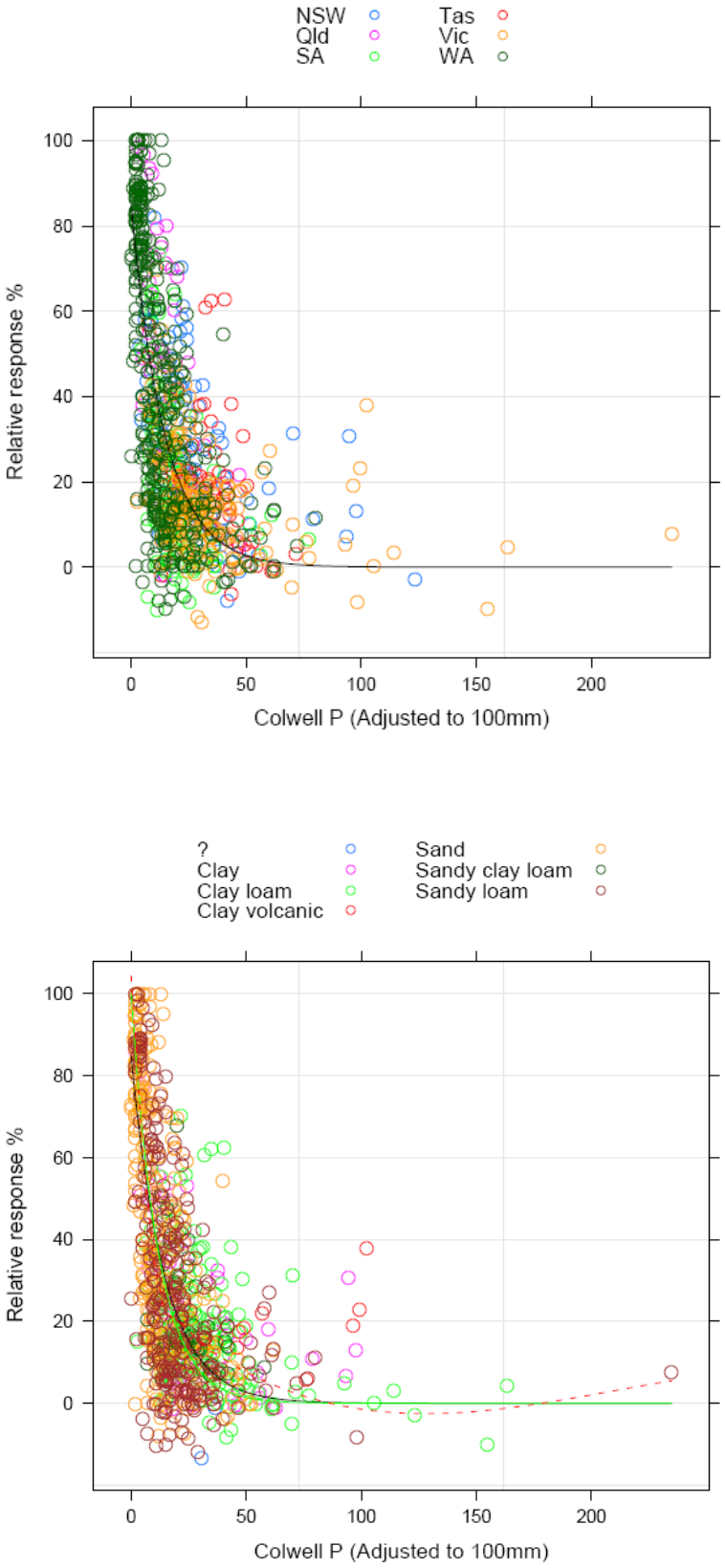


Figure 2. Relationship and data for Colwell P soil test and Relative Response values for all the combined data across Australia.

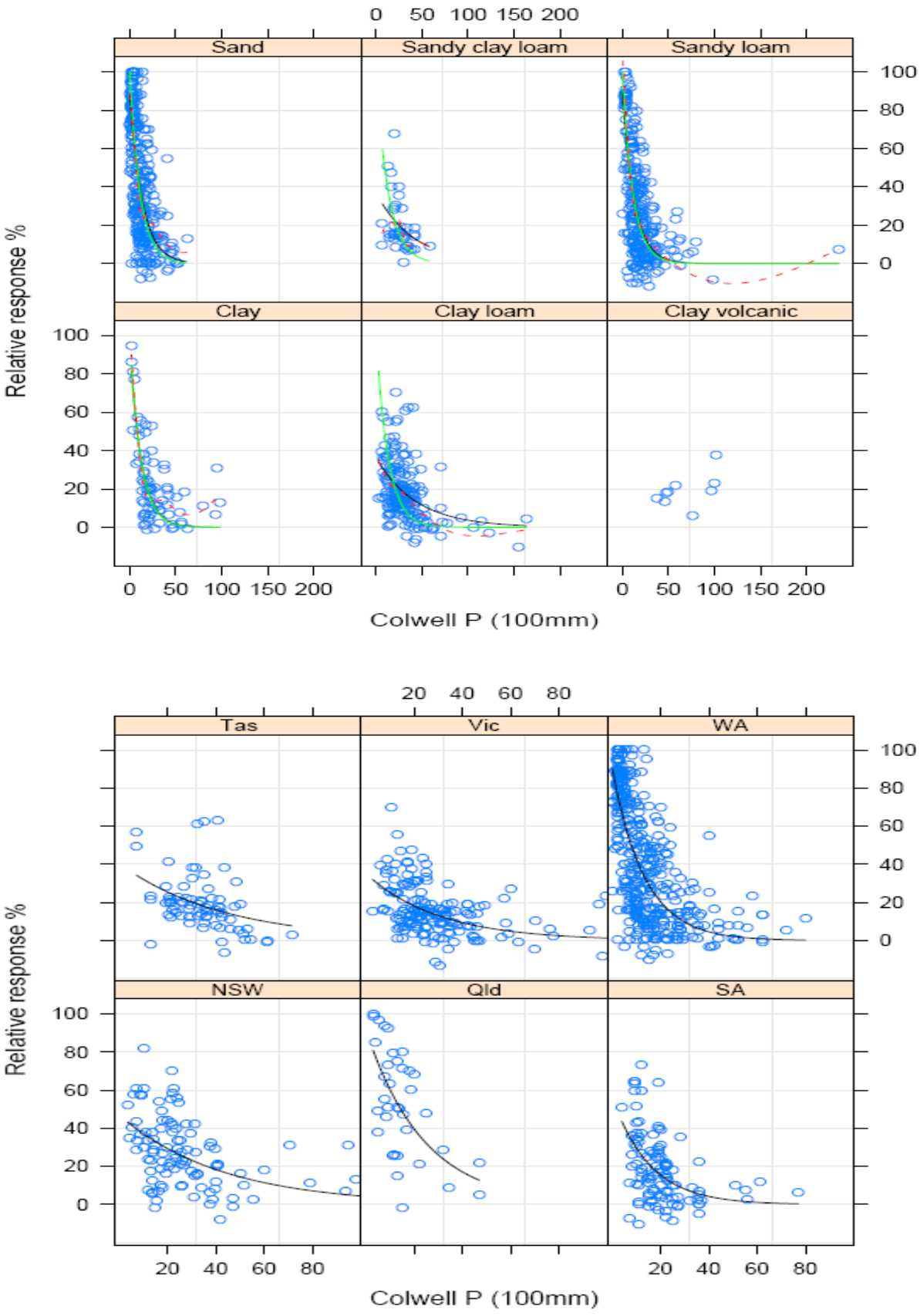


Figure 3. Relationship and data for Colwell P soil test and Relative Response values for all the combined data across Australia, split into different textual soil classes and States.

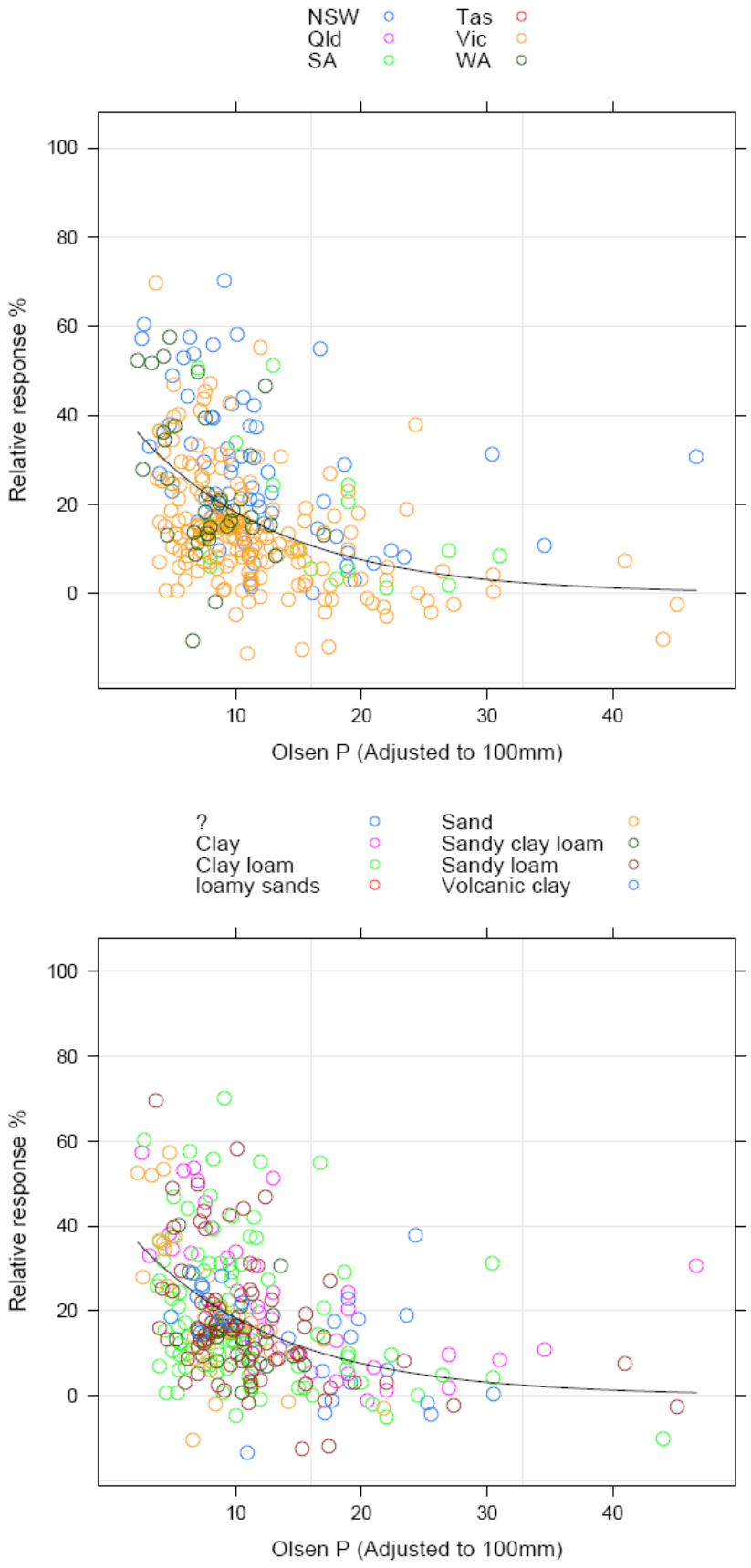


Figure 4. Relationship and data for Olsen P soil test and Relative Response values for all the combined data across Australia.

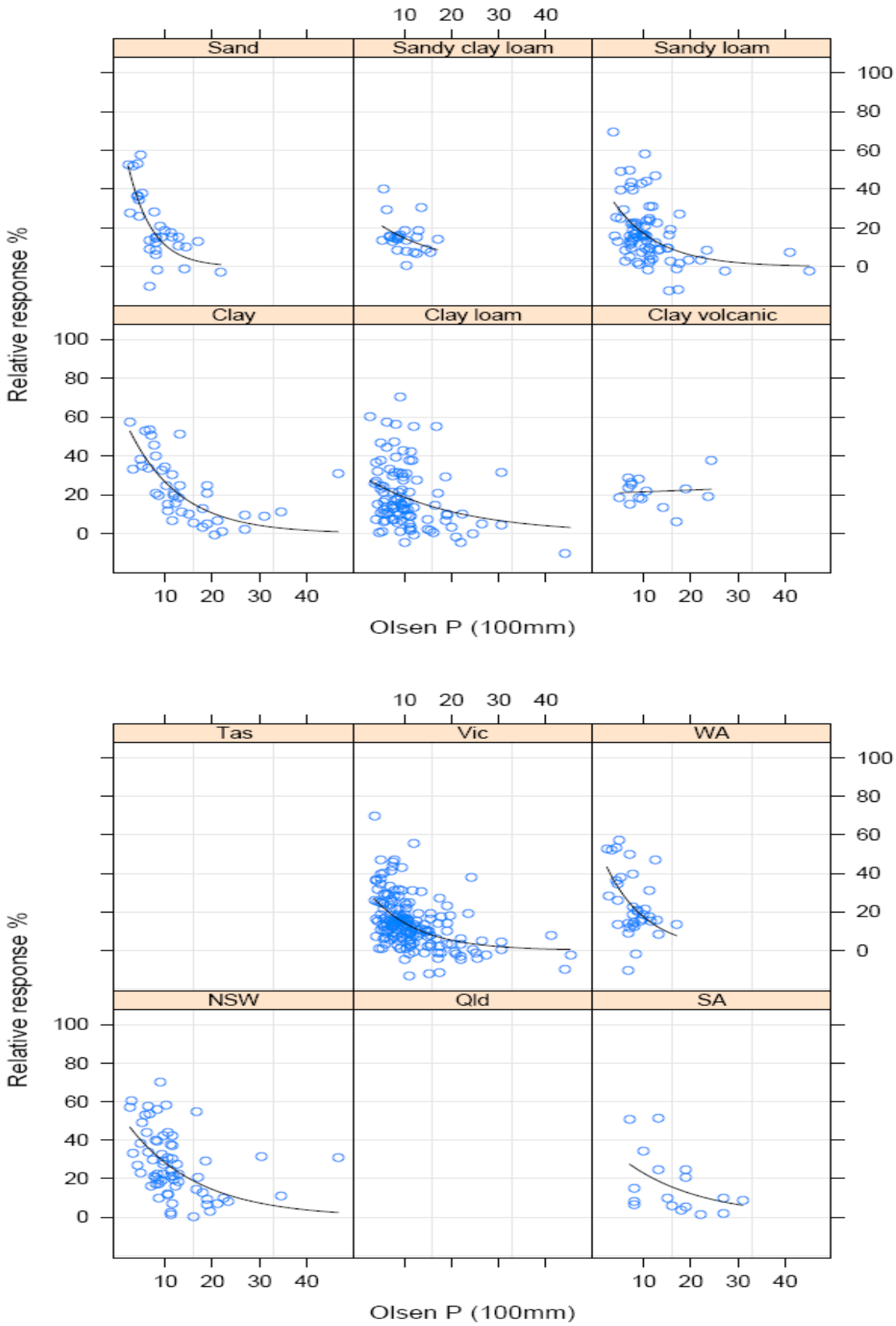


Figure 5. Relationship and data for Olsen P soil test and Relative Response values for all the combined data across Australia, split into different textual soil classes and States.

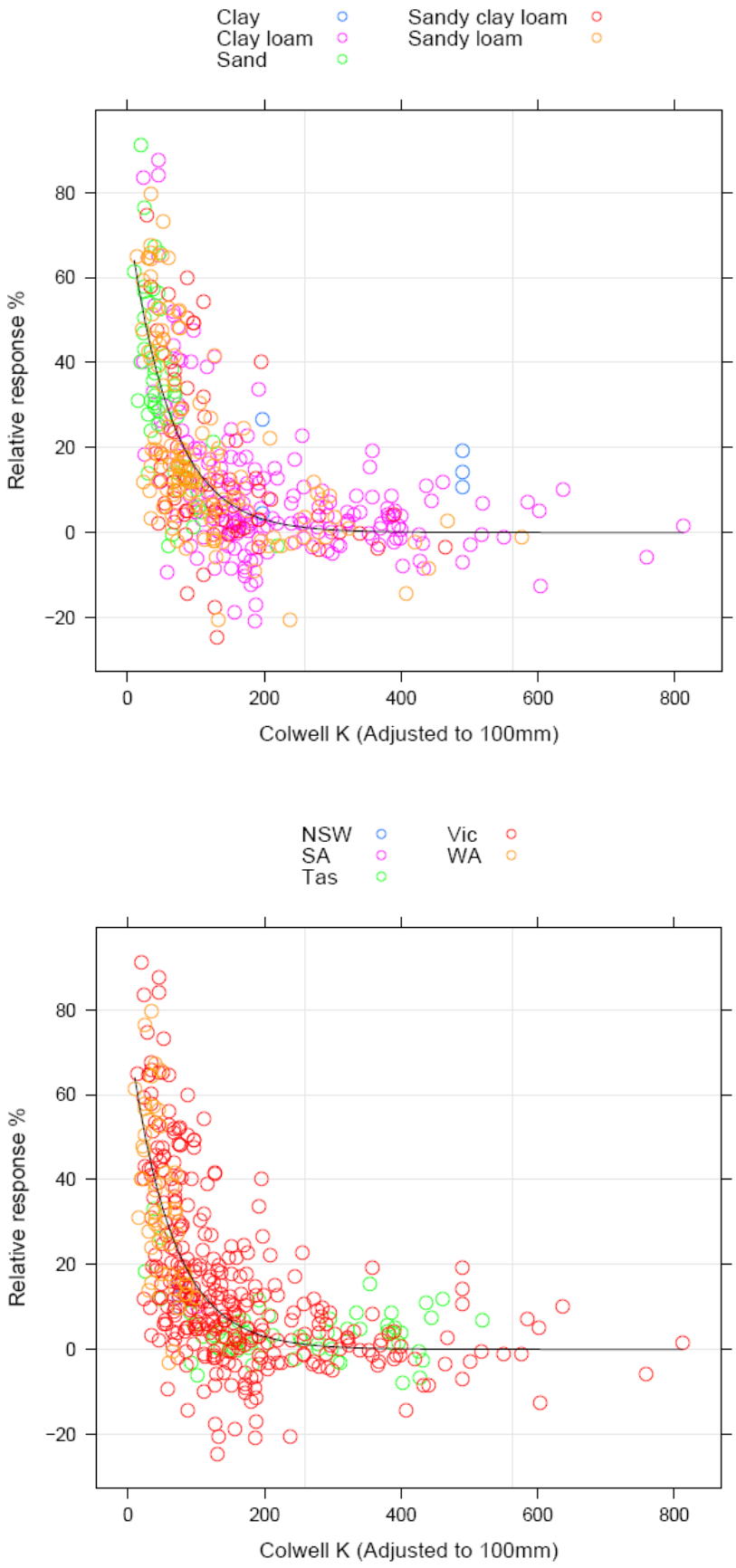


Figure 6. Relationship and data for Colwell K soil test and Relative Response values for all the combined data across Australia.

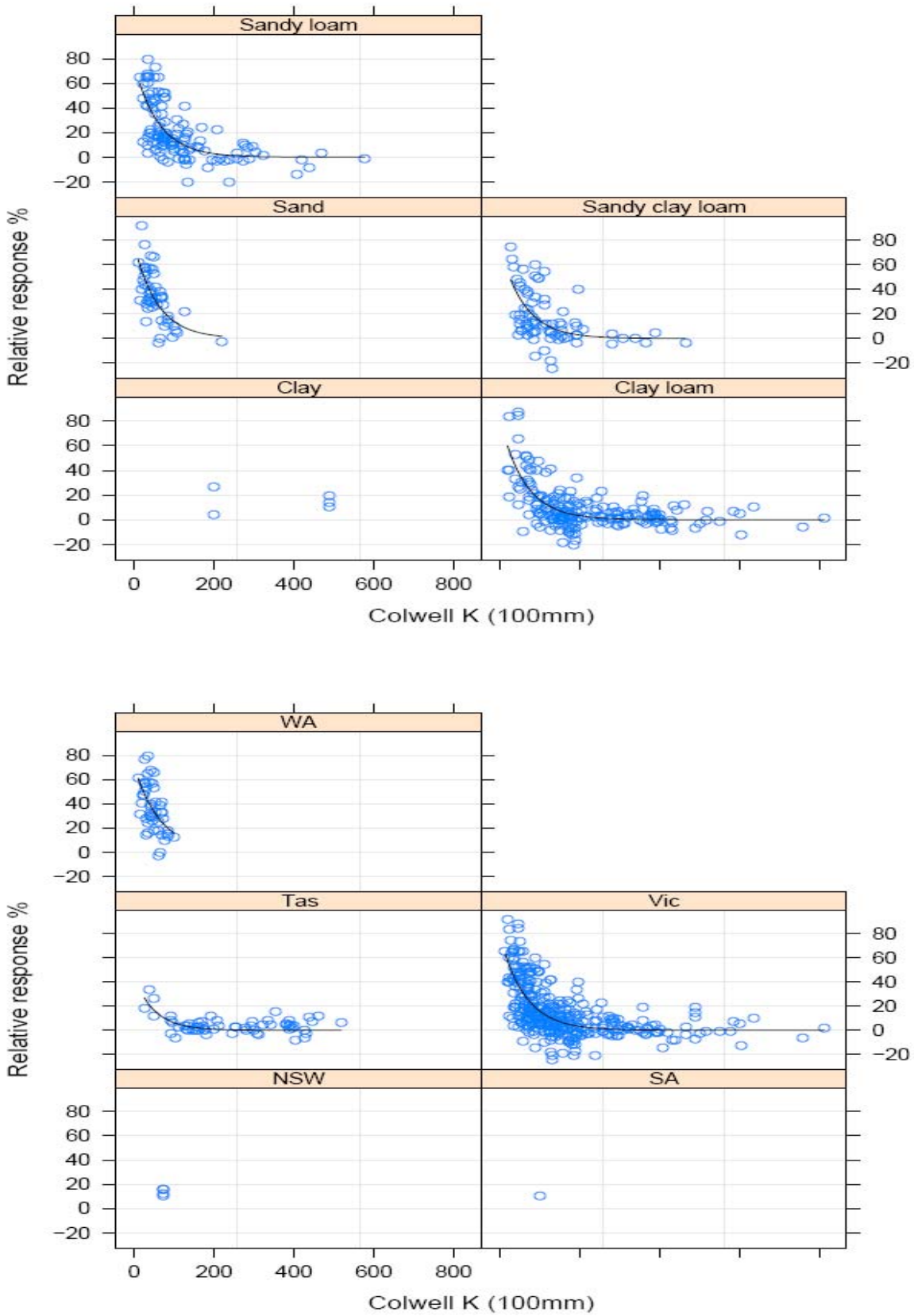


Figure 7. Relationship and data for Colwell K soil test and Relative Response values for all the combined data across Australia, split into different textual soil classes and States.

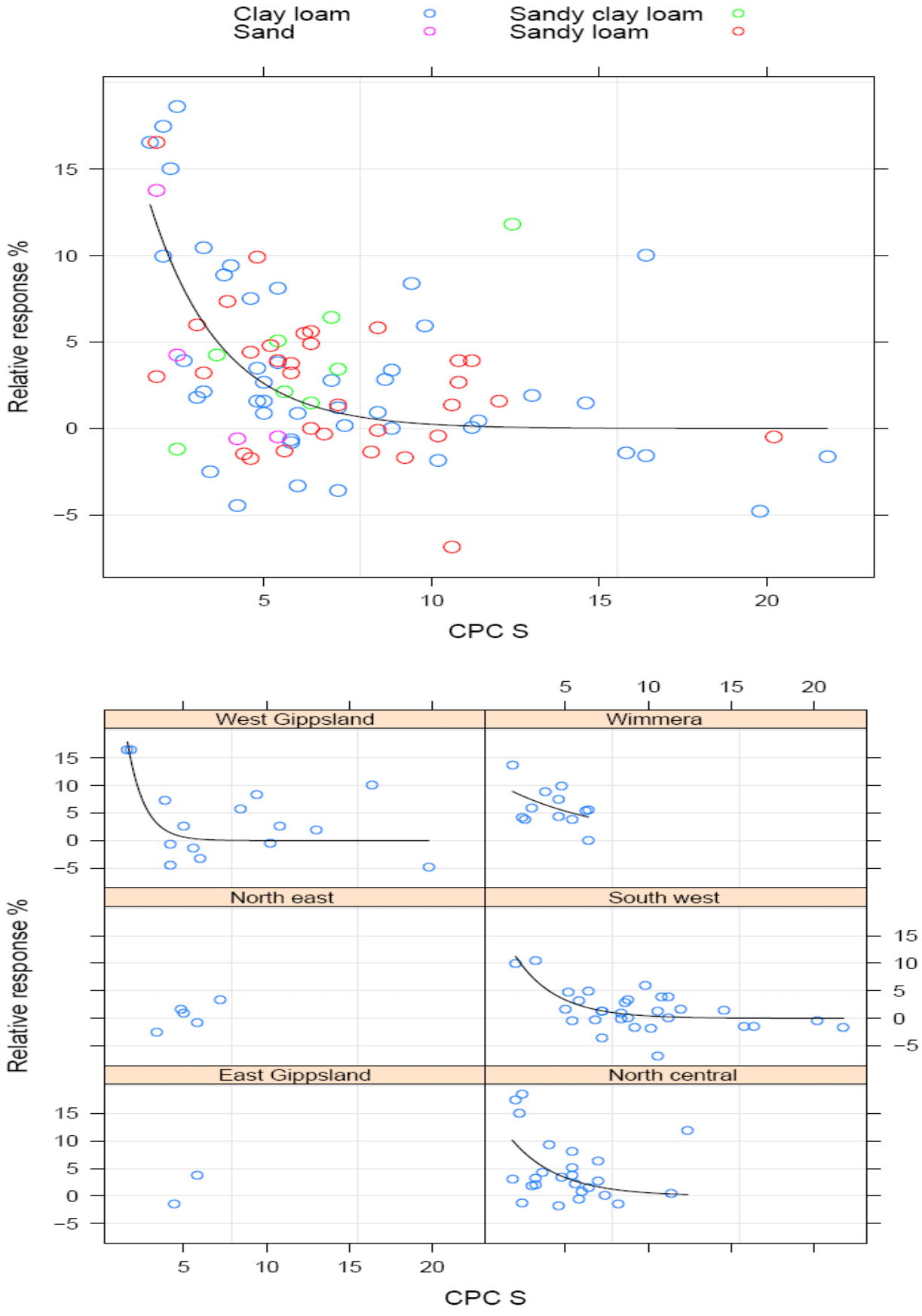


Figure 8. Relationship and data for CPC S soil test and Relative Response values for Victoria at a state and regional level.

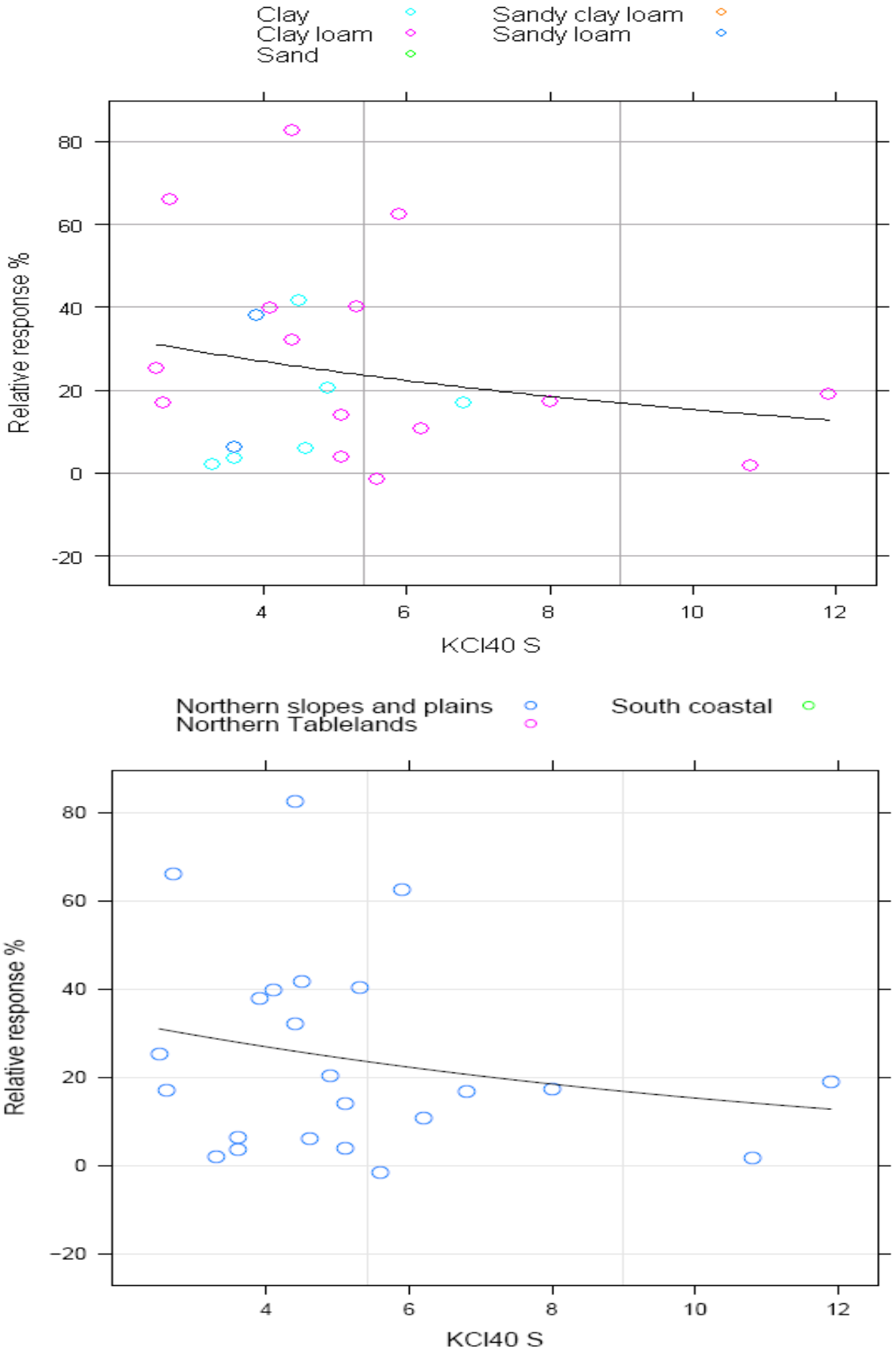


Figure 9. Relationship and data for KCl40 S soil test and Relative Response for values for NSW at a state and regional level.

Utilisation of the ‘flexi-graphing’ tool

The flexigraph tool was developed for use within relational databases by the Relational Database Unit at UNE. In the context of this database, the tool can be used to plot yield responses in high quality datasets for N rates trials. For each individual trial, it is possible to flexigraph pasture yields against rates of applied nitrogen.

The tool can also be used to plot processed data for the other nutrients. The Y axis of pasture yield can be plotted against applied nutrients or soil tests or any other recorded metadata. An example of the use of the Flexi graph tool within the data base is provided in Figure 10.

The tool is set up with an intuitive interface so that a user can select data from individual trials or in series and graph the available yield data against a number of parameters. This is selected using a “point and click” process that makes the selection of graph parameters relatively easy, given the quantities of data.

Archiving of datasets

All datasets that have been submitted have been accepted and are available through an archival capacity within the database. There are three categories of archived data:

1. Processed datasets (also available as statistically analysed data or on the flexigraph tool)
2. Transformed (dtx) files of datasets
3. Unprocessed data still in its raw submitted state since it could not be processed due to a lack of one or more of the key criteria

Future scope for using the database as a research tool

The release of the database during 2006/07 will provide more capacity to users than was initially anticipated. However, even further scope will be afforded to registered research users such as amending the current relative response curves if additional datasets are discovered and submitted or the potential to use statistical tools to merge nutrient response curves together with previously published work that has no raw data but only a regression equation (with or without standard errors). There will also be scope for investigating nutrient interactions eg. P x N; P x K; P x S etc. from multi-nutrient rates trials.

Future access for users

Dairy Australia and the other key stakeholders are committed to providing the analysed datasets (as relative response curves with interpretations) extensively to interested user groups after initial training in the use of the database.

However, access to the flexigraph tool and the raw archival material will only be available to authorised users in order to minimise the chance of misuse of the database and faulty interpretation of unprocessed datasets. Details regarding this registration process have yet to be resolved with Dairy Australia who has ownership of the database on behalf of the other stakeholders.

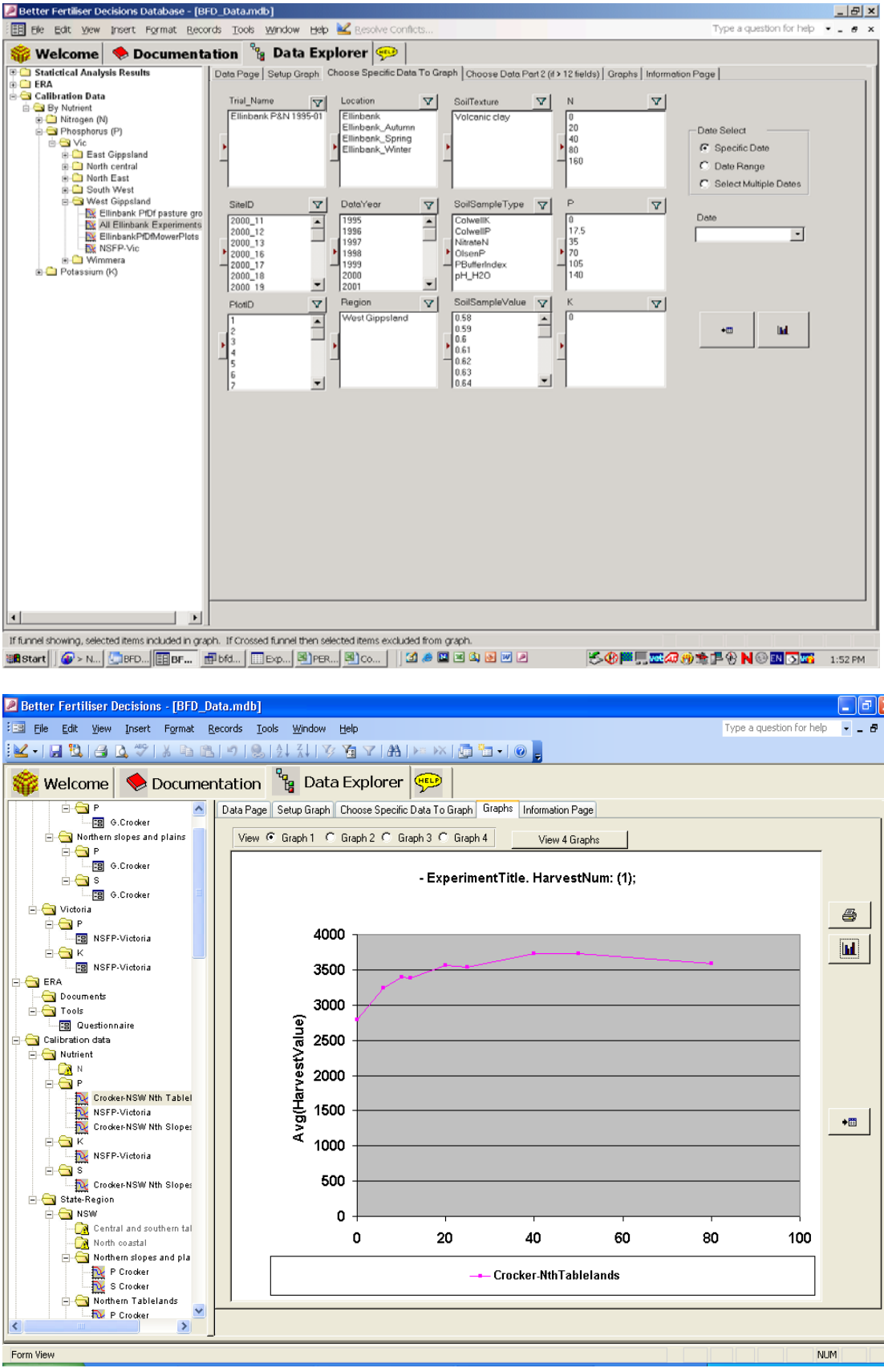


Figure 10. Examples of the application of the Flexi graphing of data sets using the Better Fertiliser Decisions Relational Data base.

On-going management and maintenance of the database

At various stages of the project it was recognised that it would be unfortunate to undertake the major task of gathering and compiling the historical data and then risk it being lost in archives again. Thus in November 2005, Nick Drew and Ken Peverill met with Blair Wood (NLWRA) and Neil McKenzie (CSIRO/ACLEP) in order to discuss the potential for the handover of the National database and its subsequent maintenance and management. Subsequently discussion were held with stakeholders who have various rights to the project intellectual property and it was agreed that DA would be supportive of the transfer of the completed database into the care of NLWRA who would engage ACLEP to manage and maintain it. This would be provisional on the other stakeholders support and the terms of a legal agreement between DA and NLWRA / CSIRO. At present, DA solely owns the generated IP and the data in its processed form while other funders and contributors have a licence to use the IP.

In early March 2006, Cameron Gourley, Nick Drew and Ken Peverill met with Blair Wood and the ACLEP team (lead by Neil McKenzie) and it was resolved that:

1. DA would prepare a draft agreement for ultimate signoff with NLWRA and CSIRO provided that the other stakeholders were satisfied. The agreement would be kept as simple as possible with the attached schedule focussing on the operational aspects. The agreement would cover issues of ownership, legal liability / indemnity, copyright issues and obligations of parties for updates and maintenance of the database.
2. The project team would prepare documentation for a ‘methods manual’ at the front access point of the database.
3. The project team would send a copy of the regional boundaries within each state to check for its consistency with the ASRIS boundaries. If they prove to be the same, the common map presentation of ASRIS could be used for the database.
4. Both ACLEP and the project team should prepare an outline of their tasks to be performed together with a budget projection in each case.

Environment Module

Background

Nutrient management is a key issue for the grazing industry in terms of both production efficiency and environmental impacts. The Environment Module was developed as an essential part of the Better Fertiliser Decisions project because:

- An understanding and awareness of potential negative impacts of fertiliser use is increasing
- Fertiliser advice has historically been based on production targets with only subjective environmental considerations (if any)
- Farmers and farm advisors need to be able to make more informed decisions about environmental and production outcomes, and
- The project provided an exciting opportunity to integrate environmental science outcomes into practical fertiliser decisions at a national scale

The fertiliser industry and farmers themselves are interested in taking a proactive and voluntary approach to environmental management. This has spurned widespread interest in the development of industry-based environmental self-assessment (eg Dairy-SAT, BEMP, Broadacre phosphorus, nitrogen and water monitoring tools (Ridley *et al.* 2003a)), environmental stewardship training (eg Cracking the Code (Fertilizer Industry Federation of Australia 2000)) and Environmental Management System accreditation schemes for Australian agriculture (Ridley *et al.* 2003b).

However, there is currently no comprehensive assessment tool that can be used by the grazing industry to specifically identify the temporal and spatial risks of nutrient movement from farms. A spatial risk assessment tool could be used in conjunction with environmental management tools to plan, monitor and progress environmental management actions both spatially within and between farms. Figure 9 shows how an environmental risk assessment tool could be used within a nutrient management context. A benefit of conducting a risk assessment when making a nutrient management decision is that it can help communicate with and educate farmers, farm advisers and environmental regulators about the many dimensions of a potential environmental problem (Burgman 2004).

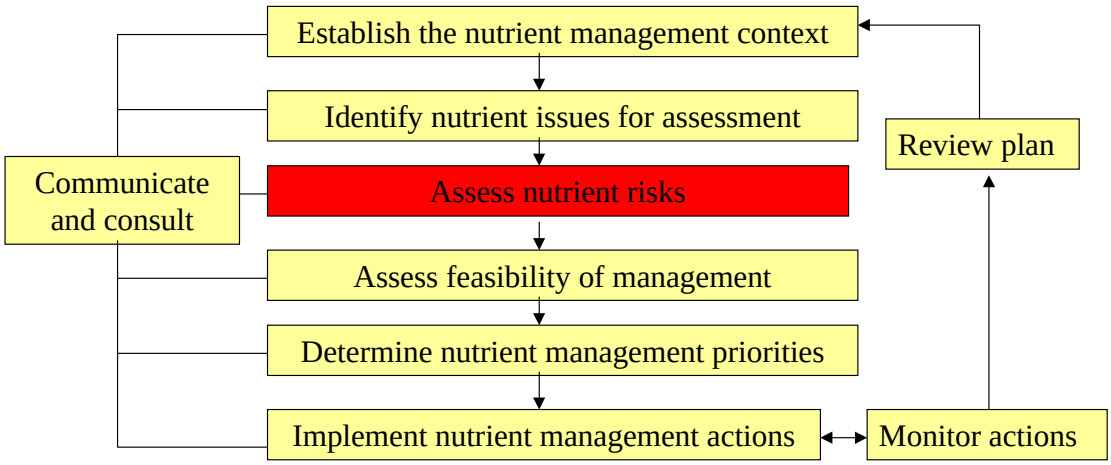


Figure 11. The role of risk assessment within a nutrient management context. Adapted from Virtue (2003) and Standards Association of Australia (1999)

An opportunity was identified within the Better Fertiliser Decisions national project to examine the processes of nutrient loss from Australian grazing farms and develop a tool to help inform farmers and their advisors about these processes. The objective of the Environment Module was therefore to draw on the body of Australian research on water and nutrient movement processes to develop a prototype environmental risk assessment (ERA) tool for Australian grazing enterprises.

Environmental impacts of nutrient loss in grazing systems in Australia

Nutrients that move off-farm from dairy, beef and sheep pastures can increase the risk of degradation of surface (Nash *et al.* 2000; Melland 2003) and ground waters (Di *et al.* 1998) through eutrophication, the risk of greenhouse gas accumulation in the atmosphere through nitrous oxide emissions (Eckard *et al.* 2003) and can decrease the biodiversity of native vegetation (Grigg *et al.* 2000).

To help define the scope of an Environmental Risk Assessment framework (ERA), contributors at the first National Network meeting in 2001, identified and ranked the major environmental impacts relating to nutrient losses from grazing systems (Table 5). Based on these rankings, the scope of the ERA framework was agreed upon by the NN as being to assess the risk of phosphorus and nitrogen losses from dairy, beef and sheep systems (including non-pasture areas) to off-farm surface waterways and groundwater and as emissions of greenhouse gases. Specifically, the framework is most relevant to pasture-based dryland grazing systems in the high rainfall zone (>600 mm yr^{-1})(Figure 12).

Table 5. Environmental impacts of Australian grazing enterprises relating to nutrients identified by National Network participants for major climate zones & management systems

Rank	Cool temperate	Mediterranean	Sub-tropical	Irrigation
1	Erosion, P in runoff	Water quality; P>N>C>heavy metals	Erosion	P in runoff and leachate
2	N leaching, Greenhouse, Acidification	Greenhouse gases	N leaching to groundwater	Nitrate leaching, groundwater quality
3	N in runoff, nutrient depletion	Nutrient depletion	Nutrients in runoff	Greenhouse gas emission
other	Pathogens, P leaching	Heavy metal accumulation in soil	Acidification	Production, reduced erosion
	Heavy metals, P:N:C	Animal health eg hypomagnesia	Greenhouse gas emission Soil impurity accumulation	

Number	Region
1	South
2	Midlands / East coast
3	North east
4	North
5	North west
6	Far north west
7	East Gippsland
8	North east
9	West Gippsland
10	North central
11	Wimmera
12	South west
13	South east
14	Kangaroo Island
15	Lower Murray
16	Adelaide Hills
17	South coastal
18	Central and southern tablelands
19	Southern slopes and plains
20	North coastal
21	Northern slopes and plains
22	Northern Tablelands
23	Darling Downs and Burnett
24	Coastal SE Queensland
25	Dry sub-tropics
26	Wet tropical coast
27	South Coast
28	Great Southern
29	South West
30	West Midlands

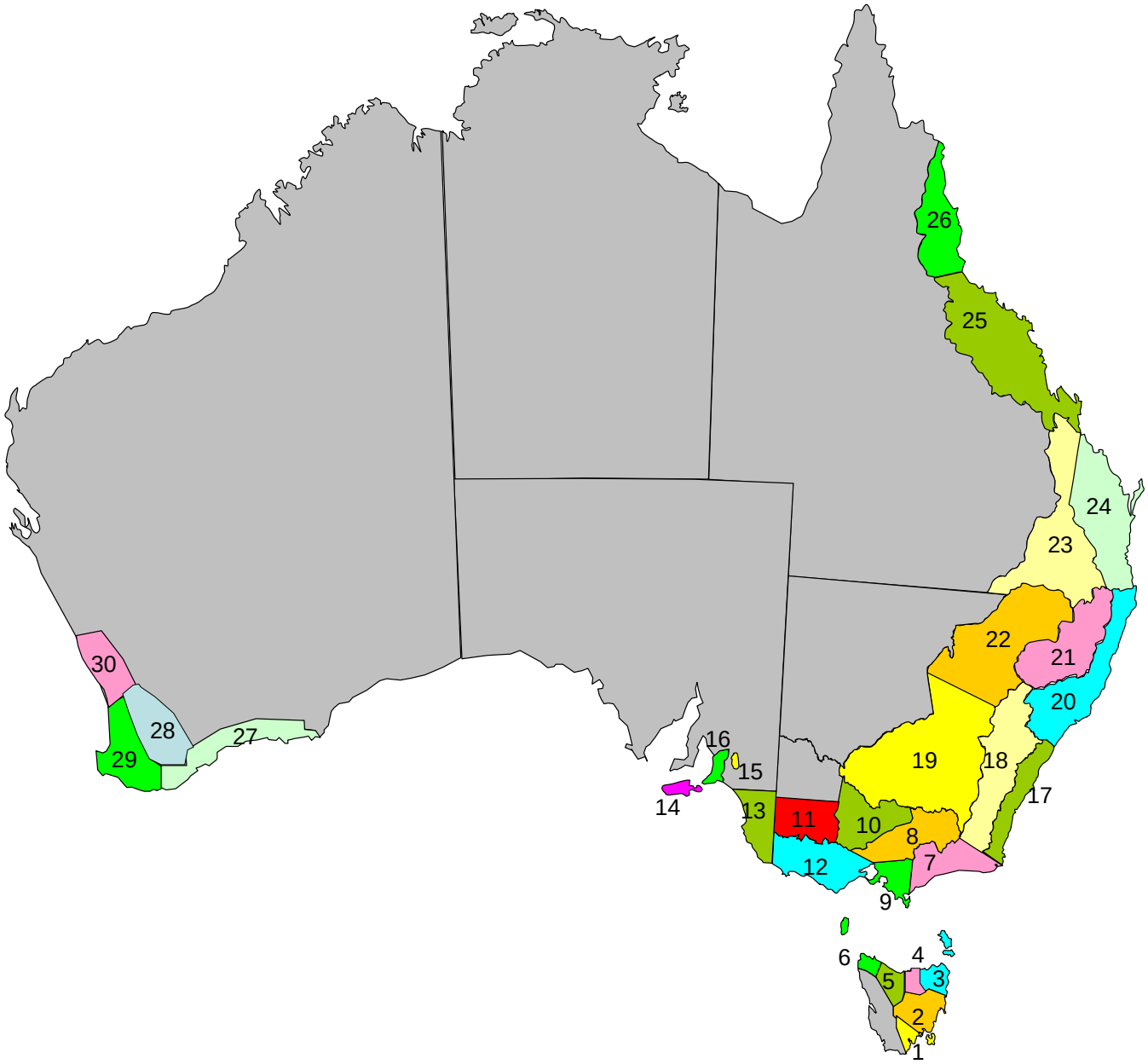


Figure 12. Grazing regions addressed by the Farm Nutrient Loss Index

Environmental risk assessment approaches

In a nutrient management context, risk can be defined as the product of the likelihood and consequence of a nutrient loss process occurring. The 'likelihood' refers to the chance of an environmentally hazardous process occurring, whereas the 'consequence' refers to the type and degree of impact. In other words, the risk of nutrients to the environment is governed by both the *potential for nutrient loss* from land, as well as the *susceptibility of the environment* to adverse ecological consequences. For example, the susceptibility of waterways to blue-green algal blooms is affected by environmental factors such as water flow rates and temperature. The risk of adverse consequences occurring can be assessed using approaches outlined in the Australia and New Zealand Environment and Conservation Council guidelines (Hart *et al.* 1999; Anon 2000). However, in order to identify the potential for nutrient loss from farms, a conceptual model that systematically identifies the likelihood and amount of nutrient loss is needed.

Conceptual models define components in a system. The components (eg. inputs and outputs, system boundaries, cycles) and causal links can be represented using mathematical equations, diagrams and logic trees (Burgman 2004). Process-based models that can quantitatively predict the likelihood (or probability) of nutrients moving from land are appropriate for research purposes. However, models that can predict nutrient losses at variable scales are characteristically data intensive and require specialist knowledge to be utilised. This complexity limits their use by farmers and advisers.

At the other end of the conceptual modelling spectrum, simple best management practice guidelines are useful for raising awareness of potentially hazardous management practices but do not usually provide advice that is specific to individual farms or paddocks.

A qualitative risk assessment at the paddock scale offers a practical alternative to quantitative modelling by allowing an assessment of the potential, or relative probability, for nutrient losses. Risk assessment and environmental risk management theories have been applied to a range of contexts such as weeds, salinity, erosion and nutrient management (Burgman 2004). One approach to distilling complex pools of data into one (or a few) numbers is through the use index systems.

There has not been as wide an uptake of risk assessment indices in Australia compared with overseas. There are many reasons for this, not the least of which is that there is less political imperative in Australia for farmers to meet environmental obligations (Gourley and Ridley 2005). However there is potential for an objective, practical and informative assessment tool to be used by nutrient management advisors. The Farm Nutrient Loss Index (FNLI), an index-type risk approach, was therefore developed for assessing the potential for nutrient movement from grazing systems.

The remainder of the Environment Module section of the report describes the way the FNLI was developed, how it is structured, and how it has been trialled and validated for use by sectors of the grazing and fertiliser industry.

Key criteria for developing an environmental risk assessment tool

At the start of the ERA development, some key features and principles of a suitable approach for nutrient management were determined. These included:

- Use simple, measurable and objective risk indicators that are regionally specific
- The method needs to be compatible with available farm data
- Identify and articulate the uncertainty associated with any output
- Ensure transparency of the main factors influencing risk to allow appropriate risk management strategies to be developed
- The procedure should be explicit, consistent & repeatable across state boundaries
- Needs to have a validation process
- Needs to be flexible in order to evolve with knowledge development
- Identify the target audience and pitch the ERA appropriately
- Avoid duplication of EMS prioritisation tools
- Should be based on sound science
- Potential to incorporate Australian Risk Management Standards
- Could include assessment of Private and Public good – cost of implementing environmental changes
- Opportunity to promote the positive impacts in agriculture – develop a framework that shows the positive as well as the negative impacts of nutrients in grazing systems

Development of the Farm Nutrient Loss Index

A number of techniques can be used to develop indices in a way that integrates and simplifies complex data without compromising the scientific credibility of index outcomes. One technique is to use conceptual or process models (eg Sun *et al.* (2003)), others use a combination of empirical and experiential data (eg. Mallarino *et al*. (2001). There is, however, a paucity of documented detail regarding how existing nutrient loss indices have been developed. The BFD project therefore endeavoured to develop the FNLI using a transparent and robust process, and to document the process accordingly.

Using concepts from similar indices as a starting point, the FNLI was developed based on a literature review of nutrient processes in pasture-based grazing systems in Australia and meetings with scientists and fertiliser industry representatives from across Australia (the 'National Network'). The FNLI was designed as both an 'educational' tool and can also be used in an 'advisory' mode to systematically assess and report on the relative risks of nutrient losses from different paddocks in pasture-based grazing systems. A selection of users from both the 'educator' and 'service provider' user groups have been actively engaged in the ongoing product development process. Technical workshops were held at nine locations throughout Australia to gain expert input into the development of the FNLI. These workshops were supplemented with on-farm assessments using the FNLI as well as workshops with farmers to gather feedback on the utility and validity of the FNLI outcomes. After the FNLI was developed from first principles, the FNLI was validated against measured field data.

Delphi and the Analytical Hierarchy processes were used to facilitate aggregation of an extensive pool of expert knowledge. This knowledge was used to cross-check against modelled and measured data. Experts consulted for technical and practical advice were nutrient management researchers, extension practitioners and fertiliser industry agronomists from across Australia and overseas. Over half of the 92 participants of the series of

regional technical workshops were from government departments and about 20% represented commercial industries (Figure 13).

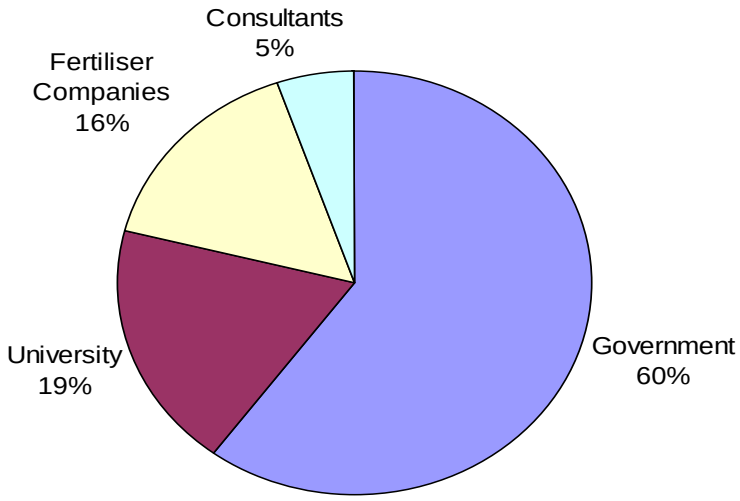


Figure 13. Affiliations of the 92 participants in BFD regional technical workshop series

Conceptual models of nutrient loss

The main factors (

Table 6) and biophysical processes (Table 7) that potentially influence nutrient losses were identified through a literature review and consultation with NN members. Initially, the main nutrient loss processes identified were: soluble P and nitrate (plus ammonium) in surface runoff; particulate P in surface runoff; soluble P and nitrate (plus ammonium) in subsurface lateral and vertical flow; and nitrous oxide emissions.

However, considering the required scope (geographical and industry) of the risk assessment tool) it was decided to address the processes influencing the loss of all forms of P and N but to only report on the total P or N loss irrespective of form.

Table 6. Factors included in an initial version of the Farm Nutrient Loss Index.

Flow transport and connectivity factors	Nutrient source and management factors
Soil profile texture & structure	Phosphorus source
Slope gradient	Soil P test (0-10 cm)
Slope shape	Fertiliser P application rate
Observed drainage class	Timing of P fertiliser application
Plant perenniality and rooting depth	Soil P retention capacity (0-10 cm)
Flow magnitude factors	Nitrogen source
Annual rainfall	N fertiliser rate
Groundcover	Timing of N fertiliser application
Flow modifying features eg drains and dams	Effluent source
	Effluent application rate
Proximity to receiving surface water	Effluent application method and timing
Minimum depth to water table	Stocking rate
	Nutrient Hotspots

Table 7. Key processes that influence the risk of loss of nutrients to the environment identified by the BFD national network

Erosion	Runoff water quality	Greenhouse gases (N_2O emission)	Nitrates in groundwater/ Acidification	Soil nutrient depletion
Ground cover; grazing management, stocking rate, species composition, soil fertility	Water management; Rainfall, hydrology – compaction, tracks, soil type, pasture, landscape, irrigation technologies and management, rainfall pattern	Soil waterlogging & water balance	N fertiliser rate & form, & N cycling	Choice of nutrient input rates (unbalanced nutrient budget)
Conservation structures	Nutrient management; Choice, rate, application, frequency, timing and where fertilisers are applied; proximity to waterbodies, nutrient budget, effluent distribution, irrigation re-use	Soil carbon content	Soil drainage characteristics & water balance, managing waterlogging, drying and wetting timings	Legume composition decline
Soil erodibility/ land use capability	Pasture productivity, Grazing management; stocking rate, pasture utilisation, grazing method	Timing of N fertiliser & effluent inputs	Soil temperature & seasonal conditions	Impacts may be episodic
Land use; periodic cropping cf permanent pasture	Mobility of P forms; Particulate, inorganic, organic P		Stocking rate; urine, N inputs, Urine hotspots	
Episodic high intensity rainfall	Existing amount and form of P in soil		Pasture spp. & health	

Regional variations in nutrient loss processes

More than thirty grazing regions throughout Australia were identified by the NN based on agro-ecological climatic conditions. It was important to have input from experts from all these regions, to ensure the FNLI would be applicable across these regions. Input was received from representatives from most of these regions throughout a series of nine technical workshops held in 2004.

The objectives of the technical workshops and farm assessments were to:

- explore and discuss the factors and processes that influence nutrient losses in grazing systems
- discuss the importance (or weighting) of each factor in the FNLI
- critically appraise the current version of the FNLI
- identify the applicability of the FNLI to different grazing systems and environments, and
- identify how outcomes from the BFD project may be useful for advisory services and R,D&E programs throughout Australia.

Harnessing nutrient management expertise and knowledge

A modified Delphi technique (Adler and Ziglio 1996) was developed for use at the workshops following consultation with Ian Tarbotton – then a social researcher with AgResaerch, New Zealand. The Delphi-technique was modified into a workshop process in order to systematically query and aggregate judgements made by the participants, as has been successfully done in similar research (Tarbotton and Sparling 2003). This technique utilised the workshops and feedback via correspondence, to allow individual contribution from all participants as well as general debate and a consensus outcome. Response data from the first three workshops (in Western Australia, South Australia and NE Victoria), were qualitatively compared. Following these workshops, the data collection process was refined and standardised to enable the responses from the subsequent 6 workshops to be quantitatively analysed. A detailed explanation of the methods used in the workshops and some of the preliminary outcomes are described by Melland *et al.* (2004).

Prior to the workshops, participants were given background information about the overall BFD project objectives, the most recent version of the FNLI. At the workshops, participants were asked to identify any factors that should be either added or removed from the FNLI. For the agreed list of factors, participants were then asked to individually rate the relative degree of importance of each factor with respect to the overall risk of nutrient loss from pastures to the wider environment. *'Risk'* was defined as the likelihood and severity of a nutrient loss process occurring. *'Likelihood'* refers to the spatial and temporal probability of process occurring eg. frequent vs infrequent runoff, and the *'severity'* of a processes refers to its magnitude eg. low vs high runoff volume.

A mixed linear model was used to analyse differences in opinion using the outcomes of the ratings exercise. The model focused on the main effect of factor, and the factor by region interactions as well as nested random effects for participant and factor within participant. Data were analysed separately for each nutrient loss pathway (eg. Runoff, subsurface lateral flow etc) using

REML in GenStat (Lawes Agricultural Trust 2004)). Statistical comparisons of factor ratings were made for the six regions where a standard method of data collection was used (Table 8).

The development of the FNLI has involved testing under a range of scenarios in which the FNLI can be used, *i.e.* enterprises (dairy, beef, sheep) and climates (winter dominant rainfall, summer dominant rainfall). In total 26 farms or research sites were visited. These included 13 dairy farms, 10 sheep and 3 beef properties. The regional workshops and field assessments were essential to clearly identify and understand the range of grazing management systems in Australia, and highlighted the complexity of accommodating all these systems in the FNLI. A side benefit was that the physical and social factors that will affect change of nutrient management practices were highlighted.

Using the expert knowledge from regional workshops

Despite the substantial differences in regional conditions, climate, rainfall patterns and soil types, the extensive regional workshop exercise showed that there was some consensus around the relative importance of factors influencing nutrient loss (

Figure 14). Across all nine workshops, there was also general consensus that storm intensity and frequency, effective rainfall, soil N status, and soil disturbance should be added or modified in the FNLI.

It was interesting to note how relatively important the ‘manageable’ (*i.e.* pasture and nutrient management factors) versus the inherent characteristics such as soil type and slope were rated. For runoff, the factors rated most important were deemed to be 'controllable' except for slope, annual rainfall and proximity to waterway, though even slope and proximity can be managed to some extent (

Figure 14).

For the subsurface lateral flow pathway, site characteristics were generally more important than management factors, and for both subsurface lateral flow and deep drainage, the N management factors were believed to be more important than P management factors. For gaseous N emission, there were fewer factors overall than the other loss pathways that were rated as having a high level of importance and most of these related to N management.

There are a number of reasons for the differences in the mean ratings of the importance of each factor – although the reasons are difficult to disentangle. Differences may be related to the variable influence each factor has on nutrient loss across the range of environments and farming systems represented. Differences may also reflect different levels of familiarity or cumulative knowledge regarding the influence of individual factors in each region.

For the six regions where a standardised data collection approach was used, detailed statistical analysis revealed the complexity of regional and factor variability. For example, there was a significant regional effect ($P<0.05$) on the mean ratings assigned to factors for the surface runoff and gaseous emission pathways (Table 8). However for all pathways, there were significant regional differences in the mean ratings for different individual factors. These interactions were not surprising given the broad range of experts, natural variability in systems and uncertainty around nutrient loss processes. Given this complexity, it was not sensible to attempt to develop individual nutrient

loss conceptual models for each region and pathway. In fact, the participants articulated that the fewer factors included in the FNLI, the more practical and likely it was to be used. However, when given the opportunity to remove or add factors to the conceptual models, only extra factors were identified. It was also not possible to use these data to assign regionally different weights to individual factors in the FNLI. This was primarily because the ratings exercise did not explicitly distinguish between the separate risks of N and P loss. Therefore, to help simplify the FNLI, commonalities in responses from the ratings exercises were used to excluded the more generically 'less important' factors and to revise and simplify the conceptual models of nutrient loss.

Table 8. Chi-square probability of differences in mean ratings assigned to factors in the FNLI across six regions for each loss pathway

Source of variation	Surface runoff	Subsurface lateral flow	Deep drainage	Gaseous N emission
Region	0.002	0.059	0.796	0.022
Factor	<0.001	<0.001	<0.001	<0.001
Region.Factor	<0.001	<0.001	0.001	0.441

Index structure

A conceptual tree was used to organise the individual factors contributing to losses of phosphorus and nitrogen. The ratings assigned to various factors during the regional workshops were used to decide which factors should be included in the conceptual models of nutrient loss for each of the four pathways;

1. surface runoff
2. vertical deep drainage
3. subsurface lateral flow
4. gaseous emission

Within the conceptual trees (Figure 15 and Figure 16), each of the pathways of loss is broken down into its 'vector' factors (*i.e.* factors that influence the flow or physical loss) and 'source' factors (*i.e.* factors that influence the nutrient pool available for loss).

There are a number of mathematical approaches for calculating risk (see Melland *et al.* (2004)). Index systems can use additive, multiplicative or minimum factor approaches to aggregate scores or values given to individual factors (Smith 1990). Multiplicative approaches are commonly used in P loss indices to reflect the principle that for loss to occur there needs to be both a source of P, and a vector for P movement.

The conceptual trees developed for the FNLI use a weighted linear additive approach. The additive approach allowed for an analytical hierarchy process to be used to assign factor weights. In most cases it was assumed that a 'zero risk' farming scenario calculated using a multiplicative approach would be interpreted and managed similarly to a 'low' risk outcome using the additive approach. Each factor is assigned a score: 1, 2, 4, or 8 using an objective set of choices. The score reflects the relative influence of that factor on the risk of nutrient loss by a pathway. The scores are multiplied by a factor-weight and added to give overall scores for the vector and source. An overall risk score

(maximum of 8) for each pathway is then calculated as the sum of the weighted vector and source factors.

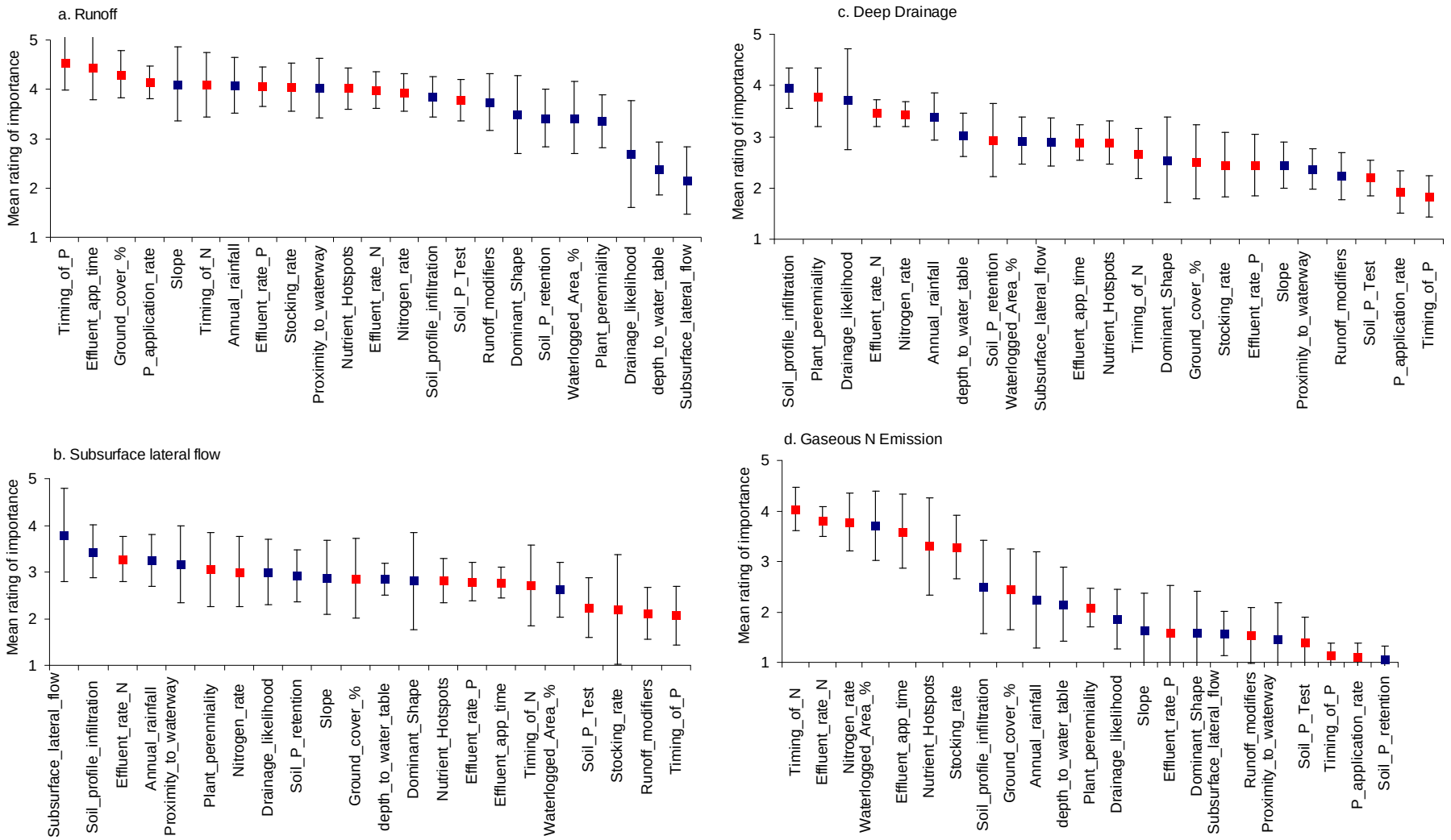


Figure 14: Adjusted mean factor ratings and SE of difference between factor means across six regions for runoff, subsurface lateral flow, deep drainage and gaseous N emission. Management factors are represented by red symbols and land characteristics by blue symbols

Factor Weights

Using the revised conceptual models of N and P loss, a subset of experts from each region undertook a more explicit method for assigning relative weights to factors. Two experts representing each grazing region were selected to individually complete an analytical hierarchy process (AHP) (Saaty 1994). The AHP is a mathematically rigorous process for prioritization and decision-making, by reducing complex decisions to a series of pair-wise comparisons, then synthesizing the results. The experts were asked to make pair-wise comparisons of the importance of factors in each branch and level of the conceptual tree such as in the case of nitrogen shown in Figure 15. By reducing complex decisions to a series of one-on-one comparisons, then synthesising the results, AHP assists decision makers arrive at the best decision, and also provides a clear rationale for the decision. The results of the comparisons were then mathematically analysed to develop the relative weights (Expert Choice Inc 2005). The weights assigned to each of the factors are specific to the region identified by the expert. Additionally the responses were usually, but not always, specific to a soil type or industry within a region. Where there were no data, the weight from a similar region and/or industry was assigned.

The paired comparison approach was successful in ascribing weights to factors that reflect empirically derived weights. For example, in the case of factors influencing the generation of runoff in the NW slopes of NSW, the ranking of factors using the expert paired comparison approach were similar to the rankings derived empirically. For three field sites where runoff was measured, the five main factors influencing volumes lost during runoff events were rainfall volume, rainfall intensity, groundcover, change in soil water content and soil depth (Murphy *et al.* 2004). These five factors are approximately equivalent to the annual rainfall and storm likelihood, groundcover, waterlogging and soil profile type factors in the FNLI. Excluding the off-farm delivery factors (runoff modifying features, dominant hill-slope shape and proximity to watercourse) in the FNLI conceptual model, the four most important empirically derived factors influencing runoff were also ranked by the same researcher as the four most important transport factors using the AHP approach. This indicated that the pair-wise comparison method, and algorithms used by ‘Expert Choice’, satisfactorily captures the expert knowledge. The equations and weights for the calculation of risk are detailed in the FNLI Technical Manual (Melland and Smith 2006).

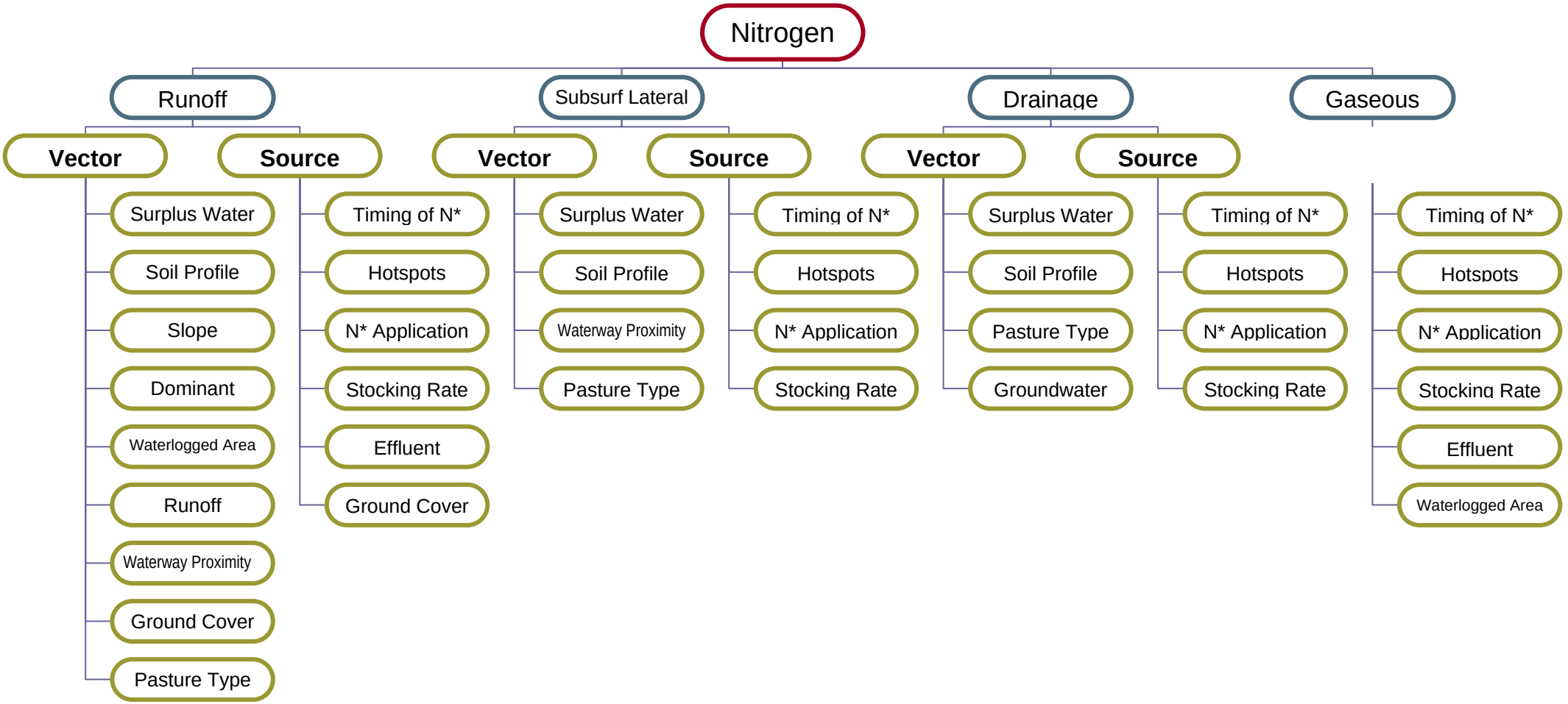


Figure 15. A conceptual framework of the factors contributing to the risk of nitrogen movement from grazed pastures. (N* refers to N as either fertiliser or effluent).

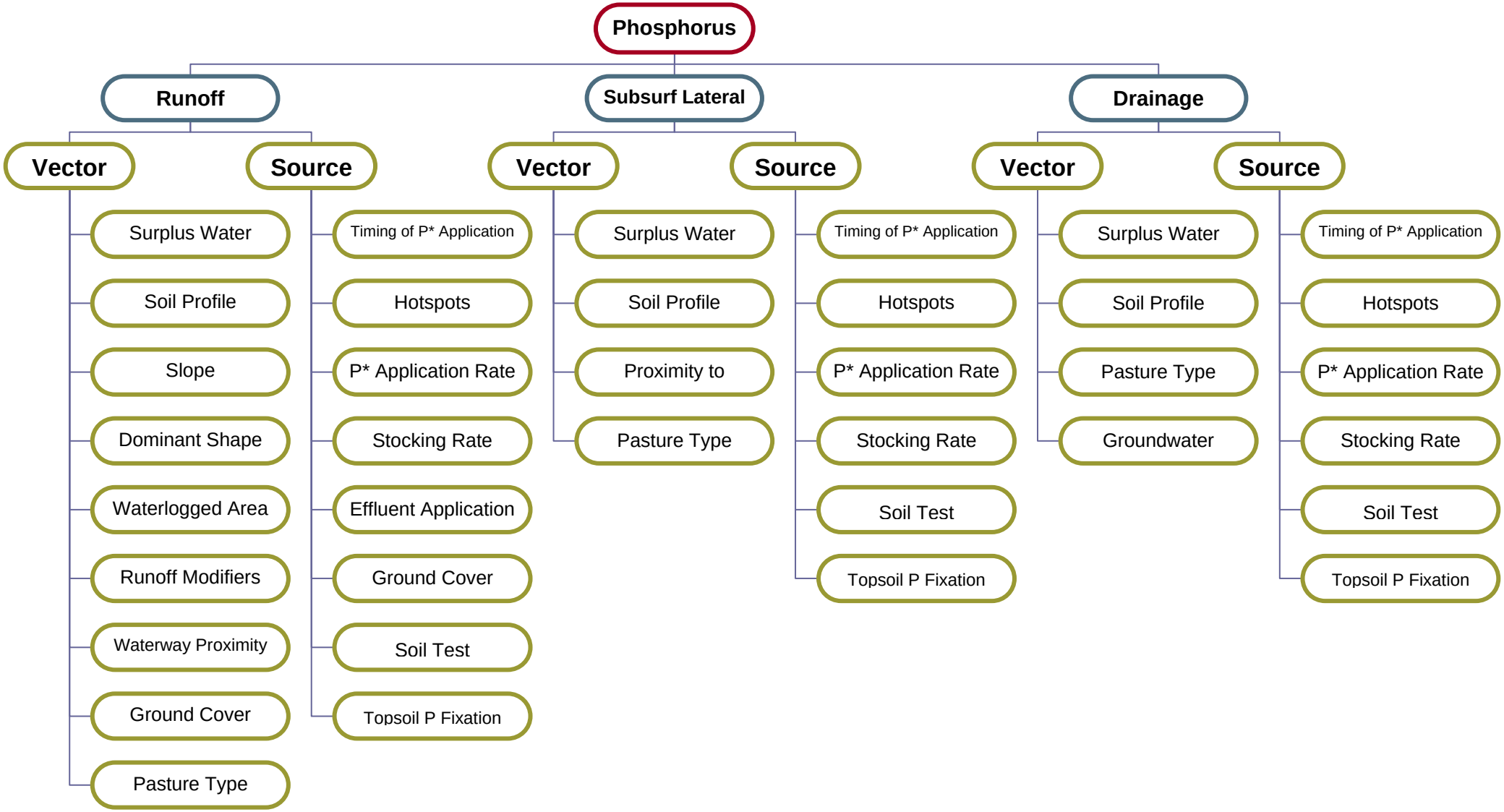


Figure 16. A conceptual framework of factors contributing to the risk of phosphorus movement from grazed pastures. (P* refers to P as either fertiliser or effluent)

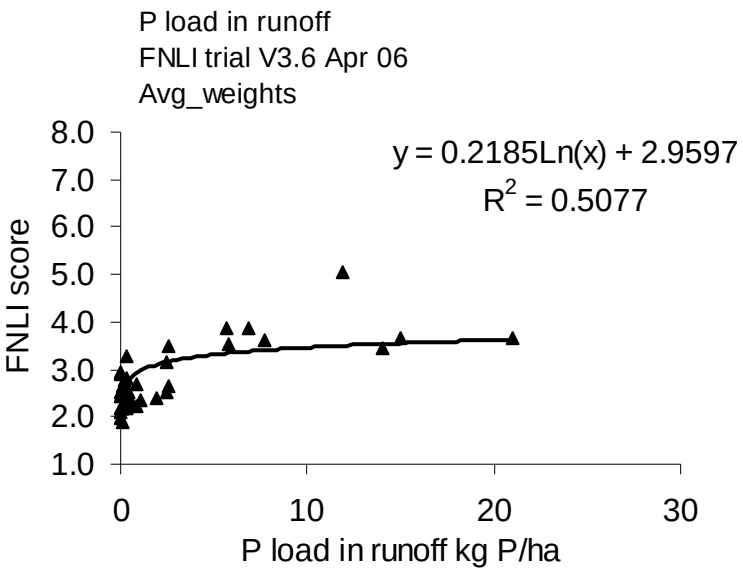
FNLI validation

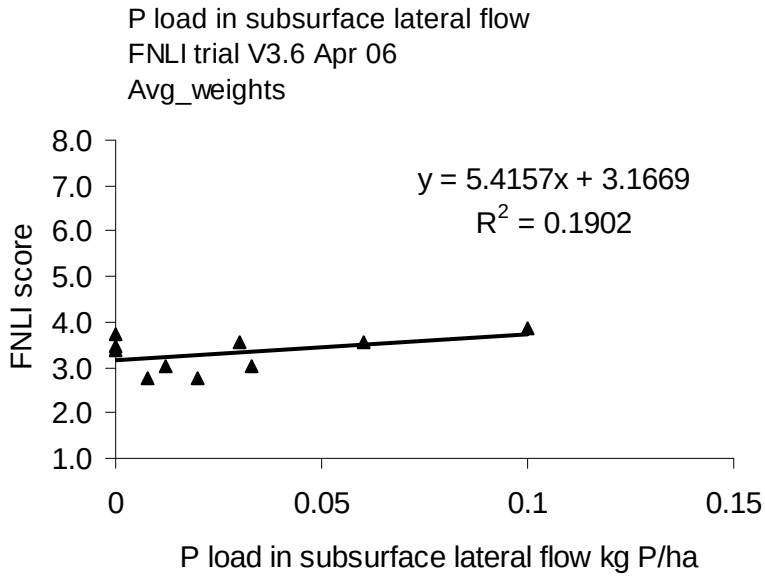
Validation of the FNLI was essential for the BFD project outputs to be considered meaningful and reliable. Validation was carried out by comparing the FNLI outcomes with measured field data. FNLI scores for individual pathways were correlated with measured nutrient losses from 17 experimental grazing sites. The comparison of modelled (FNLI) outcomes with measured data helped to challenge the conceptual models of nutrient loss, identify the boundaries for its application and identify gaps in knowledge.

There were relatively flat response relationships for most pathways (Figure 17 and Figure 18) suggesting that the scoring system needs to be modified to better differentiate between grazing systems and management scenarios. Most relationships showed reasonable correlations (R^2 = 0.45 – 0.84), except for P in subsurface lateral flow (R^2 = 0.19). In most cases P or N loads reflected edge-of-paddock losses only and did not account for off-farm delivery. However, the inclusion of these factors in the FNLI scores may to have contributed to some scatter of the data.

Overall, the conceptual models underlying the FNLI appear to satisfactorily describe losses of P and N in runoff, deep drainage and subsurface lateral flow. However P loss in subsurface lateral flow was difficult to assess because of the small losses measured. Gaseous losses of N have not been validated due to the lack of a substantial data set.

Either an ‘average’ weight for all grazing regions or individual ‘regional’ weights were assigned to factors for each pathway depending on how well either set of the weighted FNLI scores compared with measured nutrient loss. Nutrient loss by runoff, and subsurface lateral flow are best described using the ‘average’ weights, whereas deep drainage is best described using separate weights for groups of similar regions and industries. Further details regarding the calculations and weights used in the FNLI can be found in the FNLI Technical Manual. Low, medium or high nutrient loss risk rankings were then attributed to FNLI score ranges using the validation response relationships for each pathway (Table 9).


P load in runoff
FNLI trial V3.6 Apr 06
Avg_weights
y = 0.2185Ln(x) + 2.9597
R2 = 0.5077
FNLI score
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
10
20
30
P load in runoff kg P/ha


P load in subsurface lateral flow
FNLI trial V3.6 Apr 06
Avg_weights
y = 5.4157x + 3.1669
R2 = 0.1902
FNLI score
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
0.05
0.1
0.15
P load in subsurface lateral flow kg P/ha

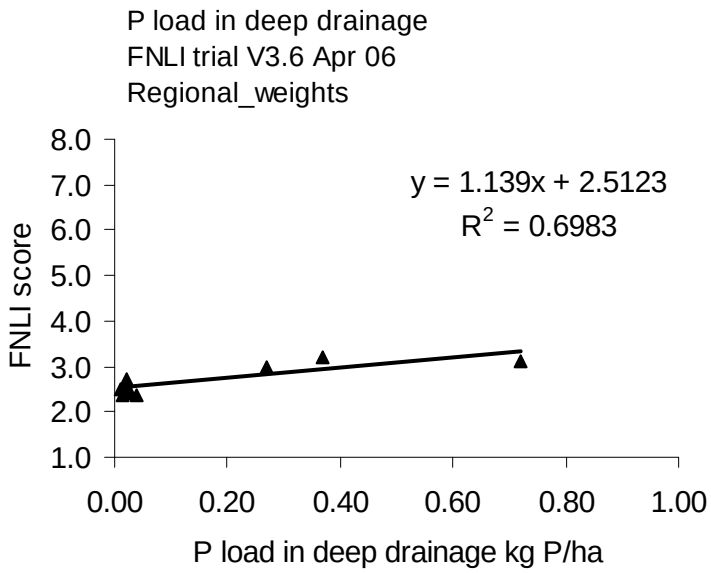

P load in deep drainage
FNLI trial V3.6 Apr 06
Regional_weights
y = 1.139x + 2.5123
R2 = 0.6983
FNLI score
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.00
0.20
0.40
0.60
0.80
1.00
P load in deep drainage kg P/ha

Figure 17: Calibration relationships between FNLI scores and measured annual average loads of P (kg P/ha) in runoff, subsurface lateral flow and deep drainage

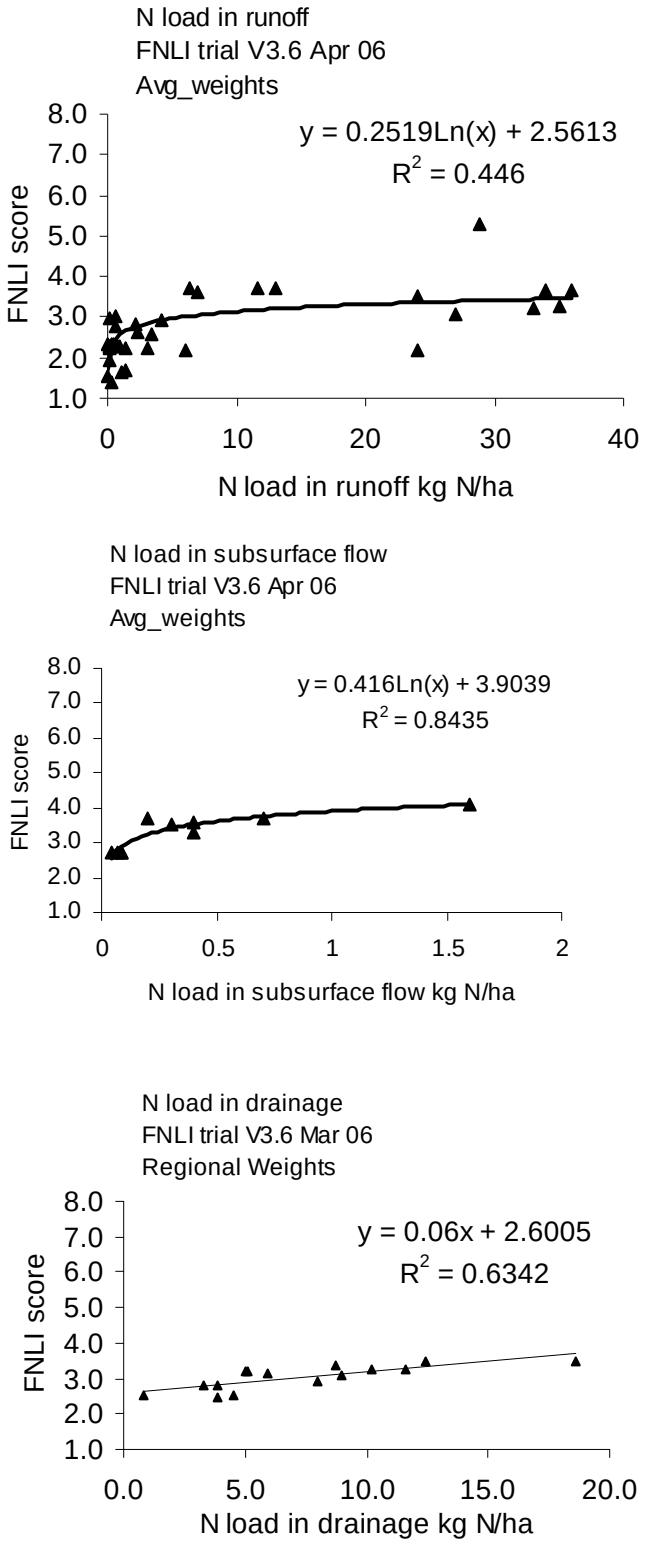


Figure 18: Calibration relationships between FNLI scores and measured annual average loads of N (kg N/ha) in runoff, subsurface lateral flow and deep drainage. One outlier site was removed from the subsurface lateral flow calibration.

Table 9. FNLI score ranges assigned to 'low', 'medium' and 'high' nutrient loss risk rankings for each nutrient loss pathway

Pathway	Weights	calibration	Low Load kg PorN/ha	Medium Load	High Load	Low FNLI score	Medium FNLI score	High FNLI score
P in runoff	Average	FNLIscore =0.2185Ln(x) + 2.9597 R2 = 0.5077	1	5	>5	3.0	3.3	>3.3
N in runoff	Average	FNLIscore = 0.2519Ln(x) + 2.5613 R2 = 0.446	5	20	>20	3.0	3.3	>3.3
P in subsurface lateral flow	Average	FNLIscore = 0.2359*x+3.4031 R2 = 0.72	0.5	3	>3	3.5	4.1	>4.1
N in subsurface lateral flow	Average	FNLIscore = 0.416Ln(x) + 3.9039 R2 = 0.8435	5	10	>10	4.6	4.9	>4.9
P in drainage	Regional	FNLIscore = 1.139x + 2.5123 R2 = 0.6983	0.5	3	>3	3.1	5.9	>5.9
N in drainage	Regional	FNLIscore = 0.06x + 2.6005 R2 = 0.6342	5	10	>10	2.9	3.2	>3.2
Gaseous N loss		No equation available	na	na	na	2	6	>6.0

Software development

During the FNLI Development Phase a need was identified to develop the FNLI into a computer based tool suitable for use by 'routine' or 'frequent' users, which could potentially be incorporated either wholly or partially into other existing decision support systems (DSS).

A computer programmer was consulted to develop the FNLI in the Visual Basic platform. The concept and framework of the FNLI DSS was endorsed by fertiliser industry representatives and the NN members. Merits of the final product include:

- Nutrient loss risks are estimated for individual pathways,
- User friendly interface,
- Objective and measurable choices for assessing each factor,
- Reasons for the risks are identified,
- The underlying complexity of the farming systems is simplified into no more than 20 assessment criteria
- Populated with regionally, and industry specific choices
- Gives help menu information such as soil and pasture types
- Generic best management practices for nutrient management on grazing farms are available
- Allows user to run different land characteristic and nutrient management scenarios

Some other features of the FNLI are shown in screenshots in Figure 19 - Figure 21. The FNLI is immediately available for uptake, adoption and tailoring by both the 'educator' and 'service provider' users during the Technology Transfer year (2006-07).

Further development of the FNLI DSS beyond the current version is outside the scope of this BFD project. A range of options are available, some of which are:

- The FNLI can readily be incorporated into other decision support systems because it was written in Visual Basic, which is a simple and transparent programming language.
- With little programming effort the FNLI could become available for use on the Internet (using Visual Basic.net) but it would require complete reprogramming for use on handheld computing devices.
- If the FNLI was integrated into computer network systems it could draw on farm nutrient histories. Client information could be saved and then recalled.

The logical future development of the FNLI would be to include it into an integrated nutrient management package. Further into the future the FNLI could be incorporated into a Geographic Information System and spatial risk maps could be produced for each paddock and farm.

Figure 19. Paddock information can be loaded from saved files.

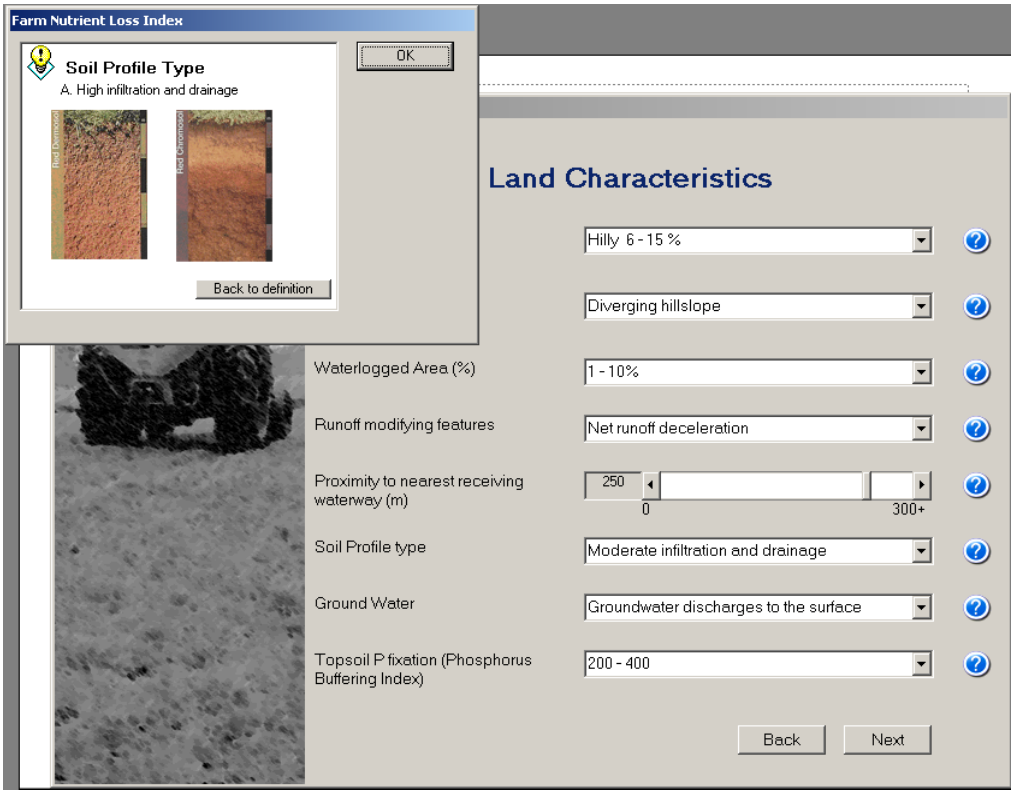


Figure 20. Each factor has accompanying 'Help boxes' with further definitions, pictures and information that assist selection of the correct response.

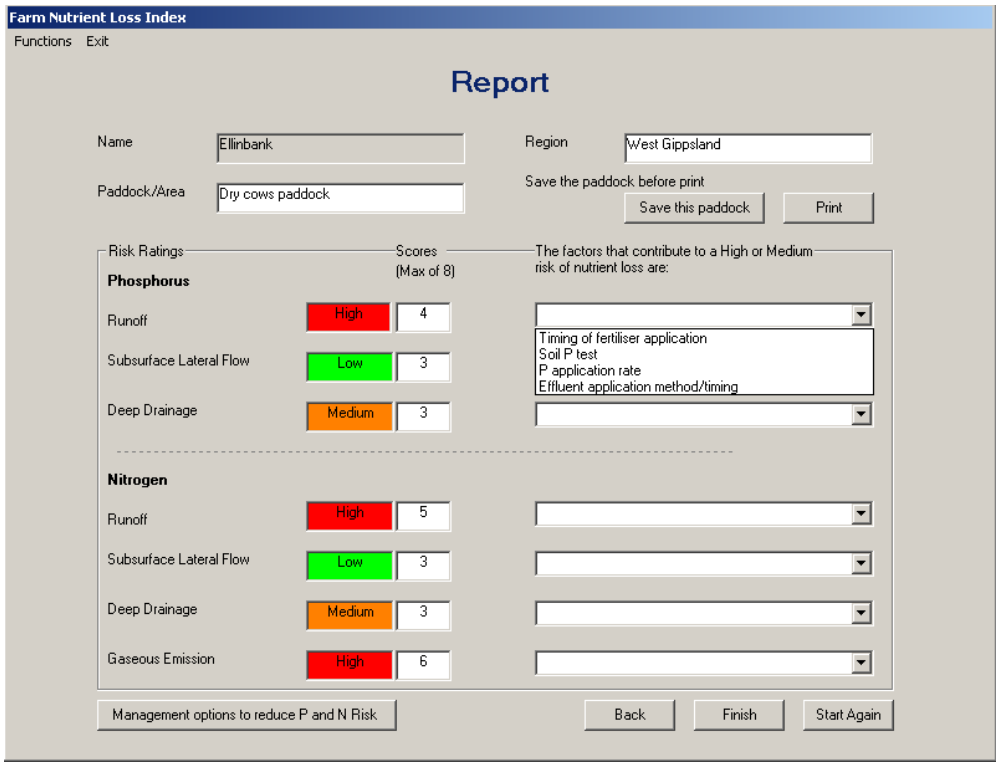


Figure 21. The Report Page shows the risk rating, reasons for 'high' or 'medium' risks, links to generic best management practices, as well as the options to print and save the report.

Road-testing the FNLI

The objective of the 'road-testing' phase of the project was to ensure the FNLI and its outcomes are useful and practical for a range of end-users. As part of this, the BFD team addressed some of the challenges commonly associated with achieving industry adoption of tools such as the FNLI.

Achieving fertiliser industry adoption and delivery of the FNLI raises two challenges. Firstly, farm DSS have traditionally focussed on the extension of production-related outcomes and off-farm impacts have not been considered. There is often no profit-driven incentive for farmers to change management in order to improve off-farm environmental outcomes, which reduces the demand from the private sector for DSS such as the FNLI. Secondly it is well recognised that there has not been widespread use of DSS for on-farm decision making, so new and innovative models of science-farmer interaction will be required to empower farmers to manage nutrients in ways that protect the environment. These challenges are described in detail by Melland *et al*. (2005).

Key reasons for the failure of many of DSS to gain support from farmers and advisers appears to be the large amount of time required for use compared to the financial return from the time invested, as well as confidence in the model. Often, a lack of effective interaction between the scientists building models and the model users, can lead to the majority of DSS being used only by those people who have been involved in their development (McCown *et al.* 2002; Black 2005). Scientists and industry personnel have therefore attempted to increase the usefulness and use of DSS by developing simpler

and more task-specific tools for farmers (Eckard and Box 1998), by engaging with the advisory sector as intermediaries for using more complex software DSS with farmers, and by involving the intended users of the DSS in their development (McCown 2002). The BFD team worked closely with the NN and fertiliser industry throughout the development of the FNLI to ensure the development process was transparent and to build trust in the scientific credibility of the tool. This approach has greater potential to lead to adoption of environmental management practices than developing the DSS in isolation and 'selling' it to the industry.

Farmers

The FNLI was used in both its 'education mode' and 'advisory mode' with farmers to identify the factors contributing to nutrient loss on their farms. Farmer workshops were held in SW Victoria, Armidale, Camden and Bega. The workshops were well received by farmers with an observation that the workshops increased their awareness of the potential for nutrient losses from their farms. The workshops aided the FNLI development through feedback on the format and content of the FNLI. The FNLI generally received positive feedback and was seen as a particularly useful tool.

The FNLI was also used on a catchment basis with farmers in the Tarago Reservoir catchment, in West Gippsland Victoria. The 11,400 ha Tarago catchment supports a wide range of grazing industries, including dairy, beef, sheep and deer. Since prior water quality monitoring has identified that significant water quality degradation occurs as a result of agricultural practices, the BFD project team (in conjunction within a National Landcare and NLWRA project) developed a whole farm nutrient management program.

A total of 22 priority landholders were invited to be involved in the development of a 'whole farm nutrient plan' for their farm. The plan included a number of awareness raising and farm assessment activities, including assessing and mapping the risk of nutrient loss across the whole farm using the FNLI. Data to complete the FNLI assessments for each paddock on 16 of the properties were collected through discussions with the landholders and surveys. Maps showing nutrient loss risk areas were then developed for distribution to the landholders.

Love *et al*. (2005) used the FNLI road testing process in the Tarago to study how (i.e what mode of use) the DSS was used by farmers and scientists. They found that there was enhanced mutual learning and communication between the BFD teams and land managers as a result of using the FNLI.

Industry trainer groups

During the final year of the BFD project the FNLI was tailored for use by the fertiliser industry, and more specifically, through the FIFA Environmental Stewardship Program, Fertcare. Background and training in the FNLI was presented to 20 participants of the Fertcare Level C training in July 2005. Feedback from participants suggested the FNLI provided meaningful outcomes for the scenarios that each participant trialled and that the FNLI could be useful in giving specific advice to individual farmers with environmental concerns. Similarly, the FNLI was used to guide discussions between the BFD team and 12 NSW farm advisors about the causes of nutrient loss from dairy farms in February 2006.

In May 2005, a series of fertiliser industry meetings were instigated to road test the FNLI. In November 2005, the group tested the FNLI and gave useful feedback on its suitability as an 'advisory' tool in terms of how it would fit into fertiliser sales service delivery, how meaningful the outcomes were, how easy it was to use and how applicable it was to a range of grazing systems.

Specialised FNLI projects

'Farm to catchment' up-scaling of the FNLI

Spatial data from the FNLI assessments undertaken on 16 properties in a Victorian catchment, is being prepared to test the utility of the FNLI as a decision support tool for identifying priority areas for management at a catchment scale. Outcomes of the risk assessments were spatially mapped across the catchment using ModelBuilder, and the ARCGis (ESRI software) tool (Figure 22). The catchment-scale maps of nutrient loss risk showed variations in risk inputs and outcomes across the catchment and between paddocks on farms (eg. Soil type runoff risk, Figure 23). For privacy reasons, the catchment risk maps cannot be published in detail here. Careful thought should be given to how and where risk maps that identify individual paddocks and farms should be displayed so as not to violate privacy rights, and to avoid undermining good will and positive approaches to NRM management.

There is potential, however, for the information generated using these tools and assessments to be used quite powerfully for identifying areas for greater investment for risk abatement strategies, and for calculating statistics such as the proportion of the catchment that has a high or low risk of nutrient loss. This methodology can also be used to directly map the spatially explicit input data layers to identify variations in the factors that influence nutrient loss across the catchment. Some of the input factors required by the FNLI do not need to be assessed on-farm because they are available as electronic resources (eg. slope) at the catchment scale. These pre-existing data layers can therefore be mapped prior to any farm assessments being conducted and used to effectively screen for high and low risk landscape areas. This would also standardise the scoring of these layers of the FNLI across multiple farms and provide information to farmers that is directly relevant to farm management practice. Similarly the terminology used in the production of this attribute mapping would be tailored to that used by the farmer and the industry (and visa versa). The main limitations for up-scaling the FNLI outcomes is that each paddock is assessed independently of other paddocks, which means that the influence of nearby paddocks or farms on nutrient loss processes is not fully accounted for.

Clearly an opportunity exists for future research and development of the FNLI in terms of multi-scale risk assessment.

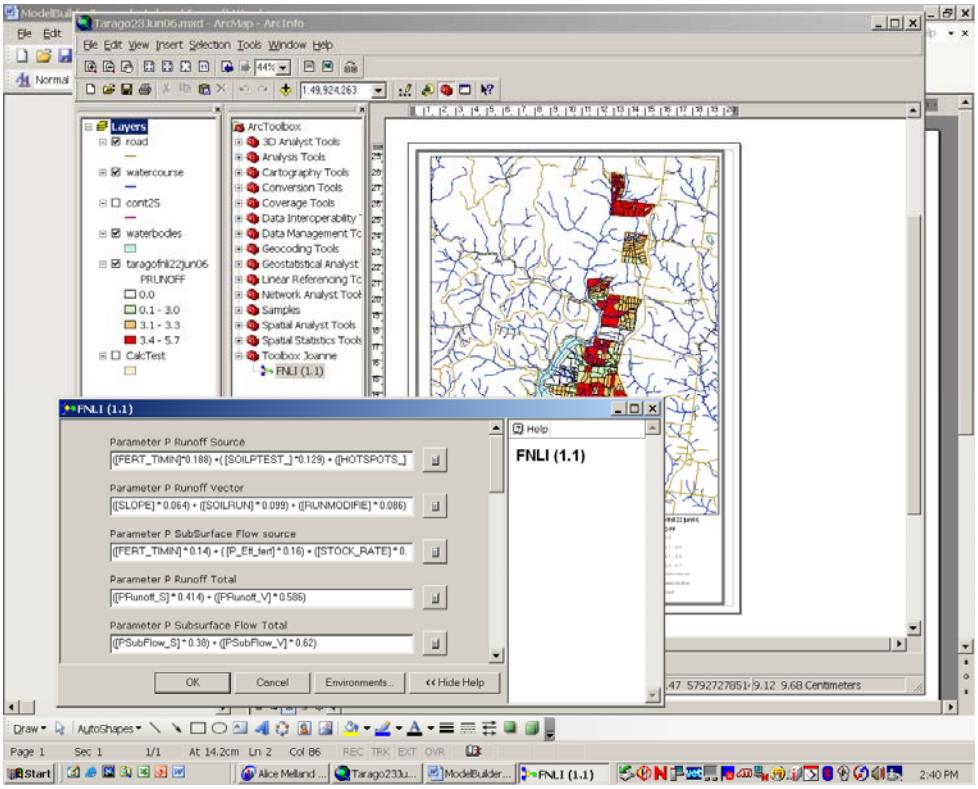


Figure 22. FNLI risk ratings for each nutrient loss pathway and paddock can be mapped across a catchment

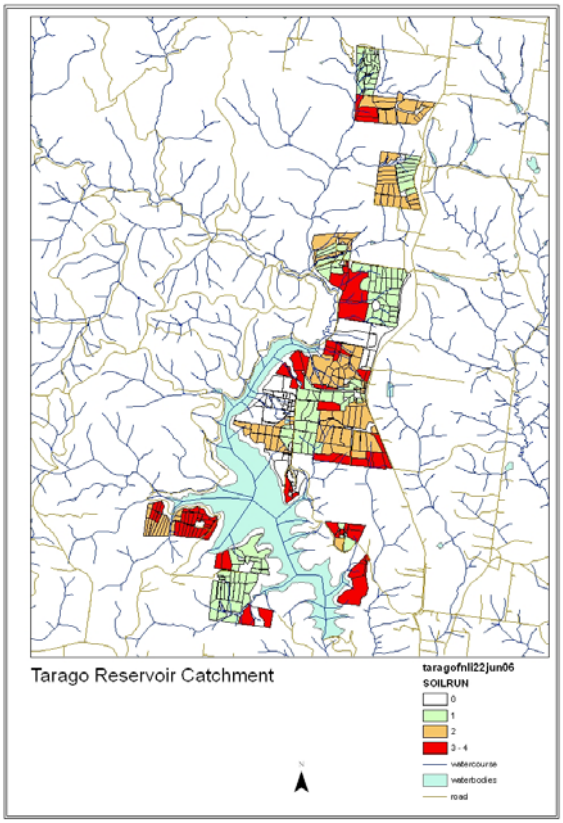


Figure 23. Variation in soil infiltration properties (0 = not assessed, 1 = high infiltration and deep drainage, 2 = moderate infiltration and deep drainage, 3-4 = moderate infiltration but poor deep drainage

Patricia Hill, a PhD student is also engaged with the BFD project in spatial mapping of nutrient loss risk at farm and catchment scale. Patricia's project proposal is incorporating the FNLI as one of the spatial assessment methods that will be investigated for identifying priority management zones in dairy farms and the Tarago catchment for nitrogen management in particular. Patricia's field survey work on a dairy farm in Gippsland commenced in September 2005.

Student Project - "Further developing the Farm Nutrient Loss Index for dairy farms through an assessment of phosphorus accumulation zones."

Phosphorus loss from farms can be exacerbated where runoff and drainage comes into contact with excessive P levels around the farm. In the FNLI, areas where there is a risk nutrients may accumulate are referred to as nutrient 'hotspots'. Nutrient hotspots include feed or watering points, gates, dairy sheds, silage pits, laneways, stock camps, yards and tracks, stock access to waterways, areas for effluent disposal and fertilisers storage and handling. Most paddock sampling programs avoid these 'hotspot' areas and there is little information on how nutrient rich these areas can become.

To investigate this factor in the FNLI, Ben Rathjen, a final year student from The University of Melbourne (Dookie) undertook a short term project "Further developing the Farm Nutrient Loss Index for dairy farms through an assessment of phosphorus accumulation zones." The aim of the project was to analyse the size, shape and concentration of phosphorus accumulation zones.

A different type of P hotspot was identified on each of 4 dairy farms; downslope of a leaky feed pad, downslope of a leaky effluent pond, a stock camp and a laneway. Approximately 100 soil cores (0-10 cm) were collected from each hotspot site from 3 to 6 m GPS-mapped grids. The soil was then tested for water extractable P (Clesceri *et al.* 1998) and the P levels were mapped.

<u>Site 1: Leaky Feed-pad.</u>

Site 1 was a pasture area immediately below a feed pad (Figure 24). In a soil sampling program carried out 4 months earlier for identifying fertiliser requirements, the entire paddock had a high Olsen P of 66 mg/kg. In the regular soil sampling program, dung patches and bare ground were deliberately avoided; however, the area below the feedpad was likely to have been sampled. The range of water-extractable P measured in the hotspot area was from 0-90 μg P g^{-1}. The intensive sampling revealed the highest concentration of P was directly below the feed pad, indicating that the feed pad was leaking P (Figure 25). The entire paddock is unlikely to have had soil P concentrations as high as those in the hotspot area. The high concentration of P below the feed pad was therefore likely to have skewed the overall paddock Olsen P result. This demonstrated the importance of identifying areas below uncontained feed pads as hotspots and avoiding these in regular soil sampling programs.

Figure 24: Site 1 – Paddock area (right) immediately downslope of a feed pad (left)

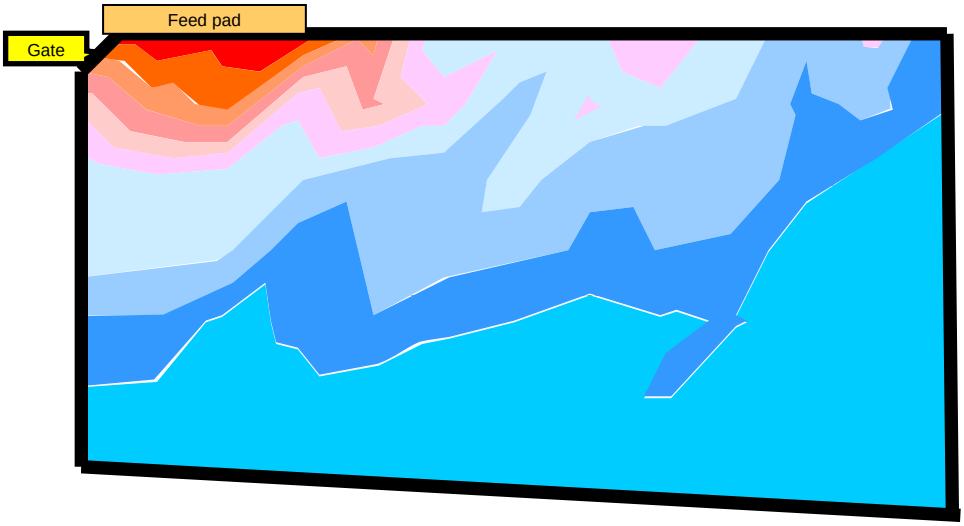


Figure 25 The distribution of water extractable P in paddock below the feed pad and gateway. A change in colour represents increases in concentration of water extractable P in 10 μg P g^{-1} increments from 10 (royal blue) to 90 (red) μg P g^{-1}. (Scale 1mm:1m)

Site 2: Effluent leaking from effluent pond.

Site 2 was an area below a shallow effluent pond where there were obvious signs of effluent overflow. The range of water extractable P measured in the Site 2 hotspot (Figure 26) was 0 – 110 μg P g^{-1}. A high level of water extractable P was found within the path of the effluent runoff and there was a good link between the visual clues (of effluent runoff) and water extractable P.

Figure 26: Site 2- Effluent leaking from effluent pond

Site 3: Stock camp

A stock camp under trees was chosen as an example of a typical hotspot found on most dairy farms (Figure 27). The range of water extractable P measured was 0-170 μg P g^{-1}. In this example the visual clues and hotspot P concentrations were also well correlated. The accumulation of P was

confined within the boundaries of the stock camp that was identified by visual assessment.

Figure 27: Site 3 - Stock camp under trees

Site 4: Laneway

Site 4 was a paddock where a laneway ended (Figure 28). Levels of water extractable P were fairly uniform across the sampled area, indicating there were no hotspots. As well as this, the water extractable P (5-35 μg P g^{-1}) was low compared with other sites suggesting that the risk of soluble P loss through runoff was minimal. The low groundcover and soil disturbance would however, infer a higher risk of erosion from the laneway than the remainder of the paddock.

Figure 28: Site 4 – Laneway in a paddock

In conclusion, a high degree of P accumulation occurred in three of the four areas identified visually as hotspots. All the 'hotspot' areas identified had a higher P runoff risk than the remainder of the paddock due to high soil P levels and/or higher erosion risk. This supports the inclusion of 'hotspots' as an important factor in the FNLI and demonstrated that visual cues such as

changes in plant species, soil disturbance, and the presence of effluent or dung can be used to detect nutrient hotspots. Visual identification (rather than intensive soil sampling) of hotspots is a sensible, rapid and cost effective way to identify nutrient accumulation zones.

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Communication Module

The communication related activities within the Better Fertiliser Decisions project have importantly maintained a strong link and focus with the next users, most notably the fertiliser industry. Discussions and regular industry meetings have reviewed the project tools and information. There has also been information directed to farmers and the broader community through the media so that the industry groups are 'primed' for project outputs. The project outputs are also receiving review from scientific peers, through national and international conferences and journal papers.

In the early stages of the project, a communications strategy was developed and approved by the PSG (Appendix 1). Communication networks already established by project stakeholders have proved to be a particularly effective means of delivering messages to all target audiences, and a number of awareness raising articles were published in the early phase of the project via industry newsletters, state department newsletters and funder newsletters. Links have continued to strengthen through the involvement in the project of industry and State organisation representatives. This has often resulted in additional coverage of essentially the same information as different stakeholders have released articles emphasising their own involvement and interest in the project. As a result, information has been circulated widely through the general rural media. It is expected that the Technology Transfer Year will further build on these networks.

The PSG and NN structures have been an important means of maintaining awareness of project progress and integration into appropriate activities. In later stages of the project an Industry Working group was established by the PSG to specifically provide feedback on the development of project outputs in both the Production and Environment modules. This has been important in ensuring that the outputs are geared for this prime route to market. Details of meetings and vital contributions by these groups are included in Appendix 2. Regional workshops organised by the FNLI team have made significant contribution to gaining feedback for the development of both the underlying process and weightings to be reflected in the index, but also on the operation of the software version.

Regular presentations to Fertcare Level C sessions have been undertaken to update the industry agronomic and retail networks on nutrient management issues on farm, how project outputs (especially the FNLI) will contribute to better management of those issues, and gain feedback on project issues such as the context of farmer interactions in the field into which project outputs may sit and FNLI software useability.

Surveys were undertaken with potential users of project outputs, such as fertiliser industry and training/extension staff, to clarify the context in which these products could be used. Industry, extension and training staff have been very useful in testing the surveys to ensure correct language and clear questions.

A 'user needs' survey particularly focused on the FNLI to ascertain relevant views on "what a useful FNLI should look like". The purpose of the survey was to gather feedback to be used to improve the *usability* of the Index, and

gather background on industry attitudes to the provision of fertiliser advice. Usability means *meaningfulness* and *ease of use* in the appropriate context. It is therefore important to understand the context in which the advice is given.

A Publications Committee was established to ensure that any scientific papers to arise from the project were appropriate and included appropriate authors given the wide range of contributors to the project. This committee has commented on the suitability of submitted scientific papers and suggested appropriate scientific journals for publication.

Awareness-raising activities

A brochure outlining the project was developed and distributed to all key stakeholder groups. This distribution included the communication networks available through stakeholder groups. In particular use was made of the extensive electronic newsletter lists used by all stakeholder groups to distribute information.

Brochure distribution list included: FIFA conference participants; DA Regional Development Programs (Gippsland, Murray, Western Vic, SA, Tas, NSW, Qld); Federal and State Environment and Primary Industry Departmental Heads; Heads of Farmer Organisations (NFF, Agforce Qld, NSW Farmers Fed, Tas Farmers and Graziers, Pastoralists and Graziers Association of WA, West Australian Farmers Federation, Victorian Farmers Federation); Non-government Environment Organisations (WWF, ACF); WA Environment Ministry Regional Managers (email distribution); GippsDairy Dairy Expo Poowong Victoria; DPI Hamilton Victoria; Cicerone Project Armidale NSW.

A project web portal was initially established by the UNE Relational Database Unit, and content managed by Paul Strickland on behalf of the project. It provided a useful communications tool, both within the Project and to the wider community, via document sharing and the opportunity for project team members on both PSG and NN to be involved in on-line discussion, but was not taken up by members of the PSG or NN to the extent it was initially hoped. The project web page was transferred to the Victorian DPI web pages when the UNE contract came to an end.

Media releases have been prepared by the project and have been used in various rural media and appropriately modified and used in industry and state government agency newsletters. Other communication activities included:

- 19 General Press articles
- 8 Industry articles
- 11 State Department newsletter articles
- 12 Industry Presentations
- 9 Fertcare Presentations

A detailed listing of communication activities is provided in Appendix 3.

Technology Transfer Year

The current funding for the Better Fertiliser Decisions project ends in June 2006, but it is important to capitalize on the strong 'brand awareness' associated with this project, and continue to build on the project products and technical and extension information. The Better Fertiliser Decisions Technical Transfer year will provide an opportunity to further embed the outputs into industry training and decision support programs and state department extension programs. This includes developing opportunities to access new audiences, and to also allow for critical analysis and discussion of the project outcomes with industry specialists, with due consideration of the implications for the grazing industries.

The Technology Transfer Year received strong support amongst the Project Steering Group and across other project stakeholders. In particular, the fertiliser industry, through individual companies such as Incitec Pivot Ltd, and the Fertiliser Industry Federation and Australia, through the FertCare program, have indicated a strong desire to implement the project outputs into existing programs, and embed the information and tools into their own 'branded' training and delivery programs.

Specifically, the Better Fertiliser Decisions Technical Transfer year will:

1. Develop a project booklet with interactive CD, including the key findings from the Better Fertiliser Decisions project, the Fertiliser Response Relational Database, and the Farm Nutrient Loss Index, which will allow ready and ongoing access to information and decision support tools.
2. Deliver of the CD and booklet to 80-100 beef, sheep and dairy advisors, targeting State government extension staff and consultants, and 20 fertiliser company and retail partner staff.
3. Conduct at least 2 training workshops on the project outputs for state government extension staff.
4. Integrate the 'Fertiliser Response Relational Database', 'soil nutrient response relationships', and the Farm Nutrient Loss Index, into the FertCare training program, the FIFA Fertiliser recommendation auditing program, and where appropriate the decision support programs of the major fertiliser companies operating within Australia.
5. Ensure that the Farm Nutrient Loss Index is available to beef, sheep and dairy producers across Australia.
6. In consultation with the Land and Water Resource Audit and the Australian Collaborative Land Evaluation Program (coordinated by CSIRO) successfully transfer of the Productivity Database to ensure its maintenance and appropriate availability through the Australian Soil Resource Information System (ASRIS).
7. Present project outputs at 3 industry conferences, and via 6 industry/state primary producer newsletters.
8. Take opportunities to report on project outputs to other key stakeholders, which may include CMA's, State EPAs, etc.
9. Submitted 4 scientific papers for publication.

Publications

Refereed Journal Papers

Gourley CJP (2004) Improving nutrient management on commercial dairy farms. Australian Journal of Dairy Technology 59, 84-88.

Gourley CJP, Ridley AM (2005) Controlling non-point pollution in Australian agricultural systems. Pedosphere 15, 768-777.

Melland AR, Smith A, O'Hara C (in preparation-a) Assessing the risk of nutrient loss to the environment from Australian grazing systems: a review.
Purpose: Describes processes of nutrient loss to the environment, methods for assessing nutrient losses and provides justification for the development of a risk assessment index.

Melland AR, Smith AP, Gourley CJP (in preparation-b) A nutrient loss index for intensive grazing enterprises in Australia.
Purpose: To describe the scope, structure of the index, the conceptual models that underpin it and the model testing and limitations.

Melland AR, Smith AP, Love SM, Gourley CJP (in preparation-c) Development of an index to assess the risk of nutrient loss from Australian grazing systems.
Purpose: Describes the methodology behind the development of the Farm Nutrient Loss Index. Expands on concepts and results introduced in the Supersoil and MODSIM conference papers, and draft workshop summary report.

Conference Papers

Gourley CJP, A.R. Melland, K.I. Peverill, P. Strickland, I. Awty, J.M. Scott (2005a) Fertiliser responses and soil test calibrations for grazed pastures in Australia. In 'XX International Grassland Congress 2005: Offered papers'. Dublin, Ireland p. 861. (Wageningen Academic Publishers).

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Gourley CJP, A.R. Melland, A.P. Smith, K.I. Peverill, P. Strickland, I. Awty, J.M. Scott (2005a) Making better fertiliser decisions for production and the environment. In ''Turning Green into Gold' Proceedings of the 45th Annual Conference of the Grassland Society of Southern Australia'. Ballarat, Victoria. (Ed. J Court) p. 102. (Grasslands Society of Southern Australia Inc.).

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Technical Reports

Grant, D., Smith, A.P and Melland, A.R. (2005) Better Fertiliser Decisions Project Report on Farm Nutrient Loss Index Technical Development Workshop for Western Australia. Albany 7th April 2004

Melland A, Smith AP (2006) 'Farm Nutrient Loss Index: Technical Manual.' (Department of Primary Industries: Ellinbank, Victoria).

Smith, A.P and Melland, A.R. (2005) Better Fertiliser Decisions Project Report on Farm Nutrient Loss Index Technical Development Workshop for Northern NSW, UNE Armidale. 6th September 2004

Smith, A.P and Melland, A.R. (2005) Better Fertiliser Decisions Project Report on Farm Nutrient Loss Index Technical Development Workshop for South Australia. Adelaide 24th June 2004

Smith, A.P and Melland, A.R. (2005) Better Fertiliser Decisions Project Report on Farm Nutrient Loss Index Technical Development Workshop for SW Victoria. Hamilton, 6th September 2004

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Smith, A.P and Melland, A.R. (2005) Better Fertiliser Decisions Project Report on Farm Nutrient Loss Index Technical Development Workshop for NE Victoria and Southern NSW. 20th July 2004

Smith, A.P and Melland, A.R. (2005) Better Fertiliser Decisions Project Report on Farm Nutrient Loss Index Technical Development Workshop for Tasmania. Launceston, 27th July 2004

Smith, A.P and Melland, A.R. (2005) Better Fertiliser Decisions Project Report on Farm Nutrient Loss Index Technical Development Workshop for Queensland. Toowoomba, 8th October 2004

Smith, A.P and Melland, A.R. (2005) Better Fertiliser Decisions Project Report on Farm Nutrient Loss Index Technical Development Workshop for coastal NSW. UWS, Richmond 19th October 2004

ACHIEVEMENTS AGAINST OBJECTIVES

The stated project objectives were as follows:

1. To provide regionally specific relationships for soil test – pasture response functions for phosphorus, potassium, and sulphur fertilisers and pasture response functions for nitrogen fertiliser (and where possible animal production responses) from existing data for extensive and intensive pasture systems across Australia, through an interactive database.

   Achieved

2. To review and develop tools that identify landscape characteristics, soils and Farm Management Practises that contribute to impacts on the environment, and to integrate Environmental Risk Assessment and nutrient response functions.

   Achieved

3. To disseminate consistent and regionally specific nutrient response relationships and Environmental Risk Assessment tools to regional industry and government networks including fertiliser company advisers, consultants, extension officers and farmers to provide greater skills and confidence in fertiliser decision-making.

   Achieved but additional work will be undertaken within the Better Fertiliser Decisions 'Technology Exchange Year'.

INDUSTRY IMPLICATIONS

Fertilisers containing N, P, K and S will continue to be a key requirement for the Australian grazing industries. Currently best nutrient management practices are broadly applied across a wide range of farming systems, landscapes and soil types. A more targeted approach to nutrient management, based on the best available information on soil test targets and nutrient losses, will lead to greater nutrition conversion efficiencies and reduced nutrient losses.

The Better Fertiliser Decisions project has delivered the most comprehensive collection and summary of soil test calibration studies ever undertaken in Australia, and probably internationally, as well as a new 'Farm nutrient loss index' to assist farmers and advisors in reducing nutrient losses from the farm. The strong partnerships developed with the fertiliser industry, grazing industries and government extension and research staff, and their involvement throughout the project, has ensured that products and tools developed throughout this project are consistent with the needs of the market.

The collection and collation of soil test calibration studies resulted in more than 4500 experimental site years of data being gathered from all states of Australia. This data has been standardised and loaded into a relational data base which has allowed information from many different experiments to be combined and used to develop new and better defined soil test calibration equations. The data has also been used to identify whether there are regional and soil textural differences influencing soil test interpretation. The extensive collection, collation, standardisation and statistical interpretation has resulted in a total of 118 new response relationships for all soil tests used (currently

and historically) across Australia. These improved equations will form the basis of national standards for soil test interpretation for the Australian grazing industries.

The farm nutrient loss index has utilised the best possible information regarding nutrient loss pathways in the development of a decision support tool which predicts the risk of phosphorus and nitrogen loss due to measurable land-use practices, soil types, landscape characteristics and climatic conditions. This tool currently allows farmers and advisers to identify specific sensitivities within the landscape they manage, and select appropriate nutrient management practices to reduce nutrient losses.

Into the future, improved adoption and application of tools like soil testing and the Farm Nutrient Loss Index can continue to make substantial improvements in nutrient use efficiency while reducing adverse environmental impacts. Advances in analytical methods and procedures are continuing to refine fertiliser recommendations and reduce costs, while GPS mapping can provide a greater capacity for 'whole-farm' nutrient planning. The application of the Farm Nutrient Loss Index, has further potential to integrate existing soil and landscape information, so that potential risks of nutrient loss can be mapped at a regional, catchment and farm scale.

FUTURE RESEARCH AND RECOMMENDATIONS

Although by no way exhaustive, the following four knowledge and information gaps have been identified.

Lack of data and precision in soil test calibration equations

The extensive exercise of collating more than 70 years of experimental data relating to the response of pasture to soil nutrient availability has highlighted that there is a lack of precision in many response relationships for P, K and S and the difficulty in combining historical data sets to assist in extrapolating across soil types and regions.

The large amount of field calibration data available for soil P (Colwell and Olsen P) and (in most regions) soil K tests (Colwell, Skene and Exchangeable K), suggests that further field calibration studies would add little value. A more extensive investigation of existing data sets, particularly drawing on additional field meta-data, would however be warranted in an attempt to develop more comprehensive predictive models of fertiliser responses. The exception to this is soil sulphur, where very limited field calibrations appear to have been undertaken for any soil test, and in particular the KCl40 test, where field calibrations are restricted to only a few regions, despite the test being used across all regions of Australia. An essential issue for any further soil test development and calibration is the development and adoption of standard experimental methodologies.

Comparison of nutrient use efficiencies under different fertiliser practices

Historically, P, K and S fertiliser applications on farms have been routinely applied in late summer/autumn and perhaps again in late winter/early spring. Nitrogen fertilisers are generally strategically used to fill pasture feed gaps, primarily in winter. The implications of these fertiliser application practices are that farmers rely on soil retention and release to provide nutrients to pasture throughout the growing season.

A growing number of farmers are now using a 'frequent fertiliser' method, ie applying low rates of fertiliser every time cows are moved to another paddock. Anecdotal evidence from farmers and consultants suggests substantial pasture and animal production gains from this approach. The growing interest in 'frequent fertiliser' applications means that refined soil test calibrations may largely be ignored by many farmers and advisors.

The retention and release of nutrients can vary significantly and is driven largely by the characteristics of soil and other edaphic conditions such as moisture and temperature. A comparison of actual production, economic and environmental implications of more frequent fertiliser applications, with the more conventional approaches, on a range of soil types and production systems would provide important information to farmers regarding efficient fertiliser practises.

Better defining policy options for improved farm nutrient management

The Australian farming sector is continuing to intensify. In the future there will be fewer and larger farms, which will use more fertilizer, support more stock, and utilise more marginal soils. This is likely to increase the major environmental impacts of nutrient and sediment contamination of waterways, and greenhouse gas emissions.

The general philosophy of policy for dealing with non-point source pollution has been towards a voluntary rather than regulatory approach, with State and National governments supporting a range of programs to encourage sustainable agricultural practices. A catchment based approach, through the use of integrated catchment management plans, is the primary way that non-point source pollution is addressed at the farm and local level. At an industry level, cotton, grains, meat, sugarcane and dairy amongst others, as well as the Australian fertilizer industry, have responded to non-point source issues by investing in research and development, and developing codes of practice aimed at abating these environmental impacts. Understanding the economic, social, political and cultural contexts of farming as well as the environmental impacts of agriculture are very important in determining the appropriateness of policy responses for Australian farming systems.

Processes of N losses at the paddock, farm and catchment scale

Nitrogen is recognised as a key driver of pasture productivity, but is inefficiently used in pasture based systems, with N losses generally greater than any other nutrient. In order to manage nitrogen cycling in catchments in an ecologically responsible manner, there is a need to better understand the processes influencing nutrient losses across scales. A significant knowledge gap exists as to how to aggregate nutrient losses such as N from the paddock to a larger catchment scale, as processes that operate at one spatial scale cannot necessarily be similarly described or modelled at different spatial

scales. Studies that link process-based investigations of nitrogen cycling to paddock losses, and then further link nutrient flows at the farm level to flows at a catchment scale are needed. A spatially referenced modelling approach that integrates hydrology, plant growth, grazing and N transformations at the paddock, farm, and catchment scales is the most appropriate way to handle such complicated processes.

INTELLECTUAL PROPERTY

The IP arising from BFD by way of the National Database and the FNLI will be in the public domain and thus access to the products will not incur licensing costs to users.

The Dairy Australia (DA) agreements with Project Funders provide that DA has ownership of the IP on behalf of all of the other stakeholders. All contributors retain ownership to the original raw data and UNE retains ownership of its background IP.

During the Technology Transfer Year access to the Analysed data (ie. the response curves and the relevant interpretations) on the National Database will be available to all stakeholders and all other relevant agencies across Australia following appropriate training of representative(s) from their organisation. Access to the Flexigraph facility and the Archived data (both processed and unprocessed) will be restricted to authorised users only to minimise the risk of misinterpretation of relationships between field and laboratory parameters and pasture yield. Following the Technology Transfer Year the database will be managed by CSIRO / ACLEP.

Dairy Australia are in the phase of finalising an agreement with the National Land and Water Resources Audit (through Land and Water Australia) and CSIRO / ACLEP that will permit the National Database to be incorporated within the ASRIS site. User availability to the database via ASRIS will ensure national exposure along with soil and natural resource and landscape datasets. The NLWRA will continue to fund CSIRO to ensure that the National Database is maintained in a fully operational state and enhance further when additional datasets are identified while DPI Ellinbank will be funded to process any additional datasets and undertake any necessary statistical re-analysis of composite datasets at a National, State or Regional level.

The FNLI software tool will be freely available within the public domain. It is being issued to all PSG and NN members as a CD product (including a Technical manual that describes the product and also provides explanatory notes regarding the development of the tool and the interpretation of the factors). During the Technology Transfer year 2006/07, the index will also be distributed widely to other agencies outside the original group of project stakeholders (eg. Catchment Management Authorities) as part of training, education and adoption phases of knowledge transfer. The principal user of the FNLI will be FIFA and fertiliser industry members through incorporating the tool within the FertCare program rollout.

EVALUATION

The project team undertook various feedback activities throughout the project, including workshop evaluations and user road testing of aspects of the project outputs, and these are reported on earlier. To gain an independent perspective from key stakeholders, it was decided to commission an independent evaluation of the project. This was undertaken by Roberts Evaluation Pty Ltd over two weeks from June 14. The full report is attached as Appendix 4. A number of messages from key stakeholders are listed below.

Achievement of objectives

The objectives were achieved in the main or will be by the time the project ends. The
timelines for objective 6 (which relates to the education package) have been extended and this is now due at the end of June 2007.

Why did national network members remain involved?

- Members of the network became involved because they had data to contribute.
- The subject area was of great interest to them.
- They saw this as an opportunity to make the data available nationally and were proud to have that happen.
- They were pleased to be part of a national network.
- They stayed involved because they felt valued because of the data they contributed as well as their input to discussions.
- They saw that problems were dealt with quickly and efficiently.
- They appreciated the professional level of project management that kept them all informed.

What will be the future use of data base and nutrient loss index?

Members of the national network are waiting to find out about how they will use the products from the project because they still want to see the final version of both the data base and the loss index. They remain generally very supportive and enthusiastic but are unsure about how information from the data base will standardise interpretations from soil tests.

Members felt that that the project team may be able to explain how the information from the data base and the index will help with consistent interpretation of soil tests to the project steering team and the national network at the up coming meeting.

Overall value of the project

The comment was made many times that the work on collecting together research data on a national data base was long over due. There were also comments, particularly by members of fertiliser companies, that the development of the nutrient loss index will be very useful to them.

At the final joint workshop of the PSG and NN, held in Melbourne on the 27th and 28th of June 2006, a discussion session was held to gain feedback from project participants. Small group discussion was held on the following questions:

> Arising from the BFD project, what opportunities can you see for future research?

Arising from the BFD project, what might change about fertiliser use?

How might you use the BFD database and Farm Nutrient Loss Index? Could you see them being used together? In what way?

Responses generally reflect a positive response to the BFD products presented to the meeting, and a number of suggestions for new research are already reflected in proposals being developed by DPI. A summary of the responses is attached as Appendix 5.

ACKNOWLEDGEMENTS

The BFD team would like to thank the entire National Network team and the Project Steering Committee, for their on-going participation at national workshops and meetings, and their enthusiastic and constructive contributions throughout the project.

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APPENDIX 1

Communications Strategy

The Better Fertiliser Decisions Project will bring together the best available information on critical soil test levels for optimum pasture production for the range of grazing regions in Australia, together with a simple Environmental Risk Assessment tool, to assist farmers and their advisers in maximising productivity with minimum environmental impact.

A key to this process is making the output of the project available to the farming community in the most effective way so that they (and the environment) can benefit from improved practices. Fertilizer companies and State Departments of Agriculture have been engaged as key stakeholders since the project inception, recognizing their key role in providing soil nutrient management advice to farmers.

It is aimed ultimately at producing change in the farming community, in the way that they manage their use of fertilisers on farm. The communications module of the project aims to contribute to these processes. International evidence suggests strongly that simply communicating information, however persuasively, is not sufficient to change behavior.[1] Thus the processes of change in any community are applicable, which have been identified as: "awareness, participation, understanding and practice change." This requires the use of existing credible networks to establish local practice norms and gain individual commitment to the program.

Whilst the Departments of Agriculture and the fertiliser industry will be the target client for project products, at the same time, the farming community needs to be made aware of the availability of the tools and of the role played by their advisors, in both the public and private sectors, in using and disseminating the project outcomes and products. Communications networks already established by Project stakeholders will be a particularly effective means of delivering messages to all target audiences and a priority activity of the Communications Module team will be to engage with those networks.

The development of a network of public and private researchers and advisors and integration with the fertilizer industries' FERTCARE® national training program will provide a sound basis for disseminating project outcomes. It should be recognized that significant outputs from the project will not be available until the later stages and early communication will need to build awareness whilst managing expectations.

The Project has significant support from all relevant State departments, Dairy Australia, Meat and Livestock Australia, Land and Water Australia and National Land and Water Resources Audit, as well as the fertiliser industry, so there is also a need to communicate clearly to these key stakeholders in order to maintain their support.

Therefore the communications strategy has two related objectives:

[1] McKenzie-Mohr, D and Smith, W, "Fostering Sustainable Behavior", 1999, New Society Publishers, British Columbia.

- A Communications about the project and its results (including to the project funders) and

- B Communicating the data and tools arising from the project.

The first objective will need to be met throughout the project, while the second will build progressively through the latter third of the project as more concrete outcomes become available, and reaching a peak of activity in the last six months.

Audiences

It is important to identify the main and other audiences for communications outputs in order to ensure as much as possible that messages are received and understood.

These audiences, and their priority, have been identified by the Project and are listed below. It should be noted that particular groupings do not mean that any particular group is to be given undue weight, but it may be that where selective decisions are required more communication effort will be directed to some target groups.

The Project Steering Group, National Network and Funding organisations are by definition integral to the project and therefore are both an over-riding priority audience and groups that have a more in-depth requirement for information on project activities. It is proposed that, in addition to material provided for meetings and other formal reporting (such as Milestone and Annual Reports), a communications section of the BFD website be provided to allow for continual, up to date access to project outputs and discussion on activities. Communications with these groups will also include personal consultation on issues related to individual expertise, circulation of draft documentation as relevant, and regular briefings.

The following discussion outlines other audience groups, any risks in failing to communicate with those groups or potential barriers to successful communication with them. These risks and barriers will need to be monitored and managed thoughout the process.

Audiences who will be the target for project outputs.

The purpose of the project is to provide good science to inform and advise the farming community, so the primary target for the communications products (objective B) will be those providing most direct advice to the farmer. It will also be important for this group to receive communications about the project as it progresses (objective A) so that they are comfortable with the outcomes and are more likely to use them.

This group primarily includes Fertiliser Industry agronomists, sales and field staff, and State Government Research and Extension Officers. It will also include fertiliser distributors, farm consultants either in private practice or working for food processors (esp in the Dairy Industry). It may also include related industries such as seed companies and spreaders, who often have

considerable direct contact with fertiliser users, and even QA bodies and wholesaling and retailing companies (who are often increasingly involved in standard setting and on-farm training). This group would specifically include the FERTCARE® project as detailed in Appendix 1. (This audience will be referred to for simplicity as **Group 1**)

Risks and Barriers

The following are some risks for the Project associated with communications with these audiences, or barriers to successful communication:

- Some of these people may feel threatened by project outcomes if they are seen to usurp their role or challenge their authority
- Some of these people may have no commitment to adopting outcomes, or finally disagree with outcomes
- There may be a fear of negative impact on company profitability
- Some may not accept the ERA framework either because it is seen as too simplistic, or impractical
- The project outcomes may be misinterpreted – or be seen as too complicated
- A barrier to communications may be that the group is too broad and with disparate needs and views

Audiences who need to know and understand the project and outputs.

For the messages focussed on the main audiences to be fully successful there needs to be support from other important sections of the agricultural industry, regulatory authorities and others likely to influence those groups. These audiences need to receive communications about the project as it progresses (objective A) so that they are comfortable with the outcomes and are more likely to encourage and support the use of Project outputs. These groups include Government policy advisors in relevant Departments (Primary Industry, Environment), Fertiliser Industry management, Farmer Groups, Special industry Groups (such as the Grassland Society of Victoria and Aust. Soil Science Society) and community based groups , primarily Landcare. This group can also supply public advocates that can be helpful in influencing other groups, especially the main and general audiences. (This audience will be referred to for simplicity as **Group 2A**)

Risks and Barriers

The following are some risks for the Project associated with communications with these audiences, or barriers to successful communication:

- If the appropriate people within organisations are not identified there is a risk that the message will not be broadly received by the organisation
- If the people within organisations who have most credibility in the field do not support the project, or are not informed, the Project will not gain sufficient credibility for outcomes to be adopted
- Some of these people may have no commitment to adopting outcomes, or finally disagree with outcomes
- Some may not accept the ERA framework either because it is seen as too simplistic, or impractical

- The project outcomes may be misinterpreted – or be seen as too complicated

Audiences who have special interests in project outputs

For the credibility of the messages focussed on the main audiences to be maintained a number of special audiences need to receive communications about the project as it progresses (objective A) and a variation of the results (objective B), albeit in most cases in a more detailed "raw" form. These groups include the science community and specialist parts of Departments of Primary Industries. This group can also supply public advocates that can be helpful in influencing other groups, especially the main and general audiences. (This audience will be referred to for simplicity as **Group 2B**)

Risks and Barriers

The following are some risks for the Project associated with communications with these audiences, or barriers to successful communication:

- Some of these people may have no commitment to adopting outcomes, or finally disagree with outcomes – critical appraisal may impact on project credibility
- Some may not accept the ERA framework because it is seen as too simplistic, not taking all factors into account

General Audience

Other groups whose knowledge could be usefully increased, and that will further provide a supportive environment for the project's outputs, could use communications about the project as it progresses (objective A) and a variation of the results (objective B) albeit likely on a simpler level. These groups include the individual farmer or farm manager, Catchment Management Authority officers, water company staff (both irrigation and waste water), "organic" certification groups, and to some extent, the media and general community. (This audience will be referred to for simplicity as **Group 3**)

Risks and Barriers

- Some of these people may have no commitment to adopting outcomes, or finally disagree with outcomes – critical appraisal may impact on project credibility
- Some may not accept the ERA framework either because it is seen as too simplistic, or impractical
- Some of these people may feel threatened by project outcomes if they are seen to usurp their role or challenge their authority

Messages

While the messages will be geared to focus on the particular interest of the audiences addressed, the overall messages from the project will be consistent. The messages to arise from the project (objective B) will be developed as the results become available over the second half of the project.

The main message about the project in progress (objective A) will be **that the provision of accurate data and scientifically validated models that will provide industry with the ability to develop improved advice to the farming community which is more consistent and credible, incorporating a thorough environmental risk analysis.**

Each group identified above (Audiences) may also have some specific messages, or variations on the main message, to align the project with their interests. Not all messages will be covered in every communication. A table setting out detailed messages for each specific audience within groups is attached as Appendix 2.

Subsidiary Messages

Group 1

- More accurate application of fertilisers will mitigate external pressure on both Fertiliser and Pasture industries, to maintain sales;
- Good Corporate PR ;
- Information developed by project can be applied to pasture and soil types across Australia;
- Project tools will assist in providing clear, consistent advice to all Advisor Staff and end customer – providing more credibility;
- Allows company/advisor to provide extra service to provide, happier (and more wealthy) customers
- The project is a rare opportunity to collect, and bring together many years of research

Group 2A

- More accurate application of fertilisers will mitigate external pressure (esp regarding the Environment), to maintain sales
- Good Corporate PR
- Industry can be promoted as efficient, “clean and green” based on good science
- The project is a rare opportunity to collect, and bring together many years of research
- The project will contribute solid science to current and future policy development

Group 2B

- Project will bring together all relevant research, demonstrate gaps, point to new research;
- Project will demonstrate direct usefulness of research
- Project will have positive impact on industry improving the science base

- The project is a rare opportunity to collect, and bring together many years of research

Group 3

- More accurate application of fertilisers mean better profits and more responsible environmental performance
- Good science applied to farms can improve profitability and improve environmental results
- The project will contribute solid science to current and future policy development

Channels

Objective A

The broad commitment by industry and government organisation offers a unique advantage for the Project communications in that all of these organisations have established networks and communications units. Communications networks already established by Project stakeholders will be a particularly effective means of delivering messages to all target audiences and a priority activity of the Communications Module team will be to engage with those networks.

The particular nature of the audiences for this project will need use, wherever practical, of the channels that are described in detail in Appendix 3 These channels will generally be trade or special interest newsletters or events (such as field days or conferences). Opportunities to present to key groups will be taken up, such as presentations to Industry Boards, Conferences and Workshops. Broader public media will be used more sparingly, and even here, more attention will be paid to more specialist trade and rural media, as a lead-in to the Web based communications where a more controlled exposition of the project and its messages can be available. Opportunistic use will be made to present the Project when stories open up on relevant topics.

Objective B

The first half of the project will focus on establishing the most appropriate means to present the Project outcomes, but it is expected that opportunities to incorporate these into existing training and advice systems will be taken up as a priority. In many cases this will likely include some web based access to project response databases and ERA tools. It will also be critical to seek to include project outputs into other communications products and channels. As mentioned earlier, FERTCARE® will be a key example of these other channels (see Appendix 1), but such activities will also include Agriculture Extension programs, software on CD and fact sheets/booklets for use by advisors, information days and the like.

APPENDIX 2

Summary of Meetings

PSG meetings

The Project Steering Group, as well as providing important oversight, advice and review for the Project, provided an important channel for communication to stakeholders to promote political, regulatory, industry and community awareness and support and gather ideas that contribute to the strategic direction of the project.

This was of great assistance in tapping into the established networks as noted above.

Important decisions taken by the PSG included the approval of the communications plan, the need for on-going placement and maintenance of the database, the need to develop an experimental protocol to avoid problems associated with any future inclusion of new data in the database, institution and responding to the independent mid-project review, authorising further funding be provided to allow additional time for the completion of the database as a result of the unexpected data volume, establishment of the Industry Working Group to provide feedback on project outputs.

Meeting dates we largely set to coincide with Project Milestones, with additional meetings at critical stages such as the mid-project review process. Meetings were generally full day meetings.

Meeting Dates:

July 22 2003; March 23 2004; October 5 2004; April 26 2005; June 1 2005; October 5 2005; April 11 2006, June 27-28 2006.

NN meetings

The national Network also provided an important venue for feedback based on their scientific expertise and industry knowledge, providing a wealth of experience and
expertise in relation to the role of nutrients in pasture production and environmental risk assessment and in research and extension.

NN members made a significant contribution to the data template that was used to submit data. Jim Scott (UNE) during early meetings urged those gathering data to try to find and submit data even if it did not comprehensively fit the template as it was an important, and possibly historic, opportunity to “rescue” science that might otherwise be lost.

It was recognised early, and never entirely resolved, that it was difficult to fully integrate the production data and the risk analysis approach produced by the Nutrient Loss Index. There was regular strong debate on the “precedence” that should be applied to the environment and production in any fertiliser recommendations.

NN members contributed strongly to the identification of audiences for project outputs and their potential level of interest. They helped to develop the sorts of appropriate outputs and the broad elements of those outputs to meet the needs of the identified audiences.

The NN and members of the 10 regional workshops, were an integral part in the development of the FNLI, and the factors that contribute vectors to nutrient losses and the weight that should be given to them in particular regional circumstances.

NN members were also used to define appropriate regions for both data and FNLI presentation to account for the difference in regional characteristics which contribute to comparable results within the region.

National Network Meetings were generally two day meetings and were scheduled with a weighting toward the early stages of the project as the NN was an important contributor to the structure and content of the project outputs. Over 30 members were present at each meeting and represented a significant in-kind contribution on behalf of their various organisations. The NN concept has proved to be very successful in achieving joint outputs that have collective ownership. So successful indeed that the model will be applied in future on a national or multi-state basis.

Meeting Dates: August 12-13 2003; 28 -29 October 2003; May 20 2004; March 22-23 2005; June 27-28 2006.

Industry Working Group Meetings

As the Fertiliser Industry was identified as the prime route to market for project outputs the Working Group provided an important opportunity to gain fertiliser industry feedback on the Project outputs, and the specific ways in which they would be used. The Industry Working Group was established as a sub-committee of the PSG but included additional members nominated by industry PSG representatives.

At the first meeting of the working group the fertiliser industry members discussed the need for control measures for access users of the flexigraph facility on the database ie. it needs to be a legitimate research usage. Discussion also centred on the statistical approach for calibration sets of data in order to optimise interpretive power.

Both IPL and Impact (using the same DSS platform) stated that they will incorporate FNLI within their DSS when it is completed. HiFert would transfer the model onto software for their agents but also wish to use it as a stand-alone product. It was acknowledged that the current limited use of soil tests by farmers will initially limit on farm impacts of the production database.

Use of the model by IPL and Impact would probably be on a sequential basis within their DSS. They would plan to take it to the marketplace late next year. Their use pattern is unclear as yet but would use it according to their agent's needs after an adequate trialling period. FNLI may not be a free service since additional information will need to be collected probably on-farm although this

could be collected when a normal farm visit for soil sampling was underway or when the farm visit related to finalising the fertiliser recommendation.

Focus for FNLI use would probably relate principally to more environmentally sensitive regions eg. Gippsland Lakes etc. and in these areas it may be on demand routinely in order to lower company risk.

The second meeting considered project outputs in greater detail including the process of statistical analysis, the meaning of Relative Response outputs from the database, the appearance and structure of the database, and experiment/trial naming protocols. It also considered the appearance and functionality of the electronic version of the FNLI.

Discussion was held on FNLI delivery mechanisms and options.
Educational aspect of the FNLI is important. Needs to come before assessment aspect.
FNLI should be road tested with spreaders and sellers, not just with agronomists

Nutrient Loss assessment procedure can be built into fertiliser recommendations for the 1-3 paddocks assessed/soil sampled each year per farm. A FNLI report can then be sent to the farmer with the soil test results and fertiliser recommendations.
Farmer can slowly build a nutrient loss risk map of the farm over a number of years in line with their staged soil testing regime.
FNLI can be a standalone software package linked to fertiliser recommendation software (through a selection button at an appropriate point of DSS)
Fertiliser companies responsible for incorporating FNLI use into their internal competency and accreditation audits to ensure it gets used by staff

Delivering FNLI through Fertcare avoids problems with needing Workplace training accreditation to deliver the training. Fert companies don't require this anyway though.
Fertcare Level C courses nearly finished and there's no imperative for re-training down the track so FNLI could slip through

Important to strengthen linkages with other DA projects such as 30:30, 20:12 and greener Pastures – perhaps get involved with their annual field days?

APPENDIX 3

Detailed listing of communication activities

Date	Activity	Title	Who To	Where
22/10/2003	Radio Interview	BFD	West Vic	3WN radio
30/10/2003	Presentation	BFD	David Weaver - WA	Ellinbank - Visiting Scientist
1/11/2003	Newsletter - Dept	Cutting through the maze of fertiliser advice	Gippsland	How Now Gippy Cow
27/11/2003	Presentation	BFD	DA Board	Regional Board Meeting
9/12/2003	Radio Interview	BFD	ABC Rural News	ABC Country Hour
1/03/2004	Newsletter - Dept	Improving Fertiliser Decisions	Tas Regions Newsletter	Tas Farmers
2/03/2004	Newsletter - Industry	Major Project to Target Pastures	Incitec Pivot Insight	Incitec Pivot Distributors
5/04/2004	Science Paper	Making Better Fertiliser Decisions – A project for better informing production and environmental decisions relating to pasture nutrient management	WA Nutrient Management Forum	Albany WA - conference
10/04/2004	Radio Interview	FNLI	ABC Rural News	ABC Country Hour
27/05/2004	Newsletter - Dept	BFD	Drench Newsletter	distributed to all dairy program staff (DPI)
2/06/2004	Newsletter - Industry	Major Project to Target Pastures	The HiFert Times	Hi Fert Distributors
8/06/2004	Workshop	Nutrient Planning Software in the US	Incitec Pivot Ag Staff	MacMillan Campus
2/07/2004	Newsletter - Dept	Tas involved in national project to improve fertiliser decisions	TOPSTUFF (Tas Dairy Industry Newsletter)	Tas Dairy Farmers
13/07/2004	News Article	Better fertiliser Decisions	Warragul	Warragul Gazette
13/07/2004	Newsletter - Industry	Benefits for bottom line, environment	Incitec Pivot Insight	Incitec Pivot Distributors
14/07/2004	News Article	Better fertiliser Decisions	Sth Gipps	Sentinal Times
14/07/2004	News Article	Better fertiliser Decisions	Victorian Rural	Weekly Times
1/08/2004	Newsletter - Dept	Experts come together to develop better Fertiliser Decisions	Gippsland	How Now Gippy Cow
1/08/2004	Paper contribution	Risk Assessment Methodologies	4th International Phosphorus Transfer Workshop	University of Wageningen, Netherlands
2/08/2004	Presentation	Making better fertiliser decisions for grazed pastures in Australia	FIFA	Qld - International FIFA conference
7/08/2004	Newsletter - Industry	Benefits for bottom line, environment	The HiFert Times	Hi Fert Distributors
10/08/2004	Presentation	Improved nutrient Management on commercial dairy farms in Australia	DIAA	Melb - National Dairy Conference
14/09/2004	News Article	Australia wide fertiliser research project	NW Vic	Sunraysia Daily
14/09/2004	News Article	Project to help save dollars for Aussie farmers	Sth Aust	Yorke Penn Times
15/09/2004	News Article	Milestone for Pasture Report	Victorian Rural	Weekly Times

15/09/2004	Newsletter - Industry	Benefits for bottom line, environment	DA	RDP-echat
15/09/2004	Presentation	BFD	FIFA	Melb - Fertcare Program Launch
2/11/2004	Radio Interview	Fertiliser price rises make wise use increasingly important	SA	SA radio
3/11/2004	Radio Interview	Fertiliser price rises make wise use increasingly important	West Vic	3WN radio
11/01/2005	News Article	Fertiliser price rises make wise use increasingly important	NW Vic	Sunraysia Daily
16/02/2005	News Article	Fertiliser price rises make wise use increasingly important	Sth Aust	Yorke Penn Times
16/02/2005	News Article	Fertiliser price rises make wise use increasingly important	Victorian Rural	Weekly Times
6/04/2005	Newsletter - Dept	Back to the fertiliser future	Gippsland	How Now Gippy Cow
10/04/2005	Workshop	FNLI	Gippsland	Tarago Nutrient Management Plan Field Days
12/04/2005	News Article	Benefits for bottom line, environment	Gippsland	Warragul Gazette
6/05/2005	Newsletter - Dept	BFD sets the national standeard	Gippsland	How Now Gippy Cow
15/05/2005	Presentation	BFD	Victoria	Statewide Bestwool/Best Lamb Co-ordinators Conference
6/06/2005	Presentation	BFD	Gippsland	Leongatha Gippsland Beef EMS Monitoring Tools Info day
19/06/2005	Workshop	FNLI	Gippsland	Tarago Nutrient Management Plan Field Days
20/06/2005	Presentation	Better Decisions for Production	Southern Australia	Grasslands Society of Southern Australia Conference - posters
21/06/2005	Newsletter - Industry	National dairy fertiliser guidelines by 2006 aim to protect environment and productivity	DA	DA News
21/06/2005	Newsletter - Industry	National dairy fertiliser guidelines by 2006 aim to protect environment and productivity	DA	RDP e-chat
21/06/2005	Presentation	Better Decisions for the Environment		Grasslands Society of Southern Australia Conference - posters
7/07/2005	Presentation	BFD		Dookie MLA Meat for Profit Day
10/07/2005	Radio Interview	Better fertiliser Decisions	Victorian Rural	Country Roundup
6/09/2005	News Article	Better Fertiliser Decisions can save you big dollars	Southern Victoria	Southern Farmer
21/09/2005	News Article	Put soils to the test	Victorian Rural	Weekly Times
6/10/2005	Newsletter - Dept	Profitable Fertiliser decisions, I'd like to see that!	Gippsland	How Now Gippy Cow
1/12/2005	Presentation	FNLI	Statewide Extension staff	Meat and Wool team conference
24/01/2006	News Article	Sustainable production continues - Whole Farm Nutrient Planning	WestGipps	Warragul Gazette
Spring/Summer 05	Newsletter - Dept	Back to the fertiliser future	Victorian Rural	Primary Voice
Summer 05	Newsletter - Industry	BFD	MLA	Prograzer

APPENDIX 4

EVALUATION REPORT

Making Better Fertiliser Decisions
For
Grazed Pastures in Australia

Prepared for the project manager

Department of Primary Industries
Victoria

By Roberts Evaluation Pty Ltd

June 2006

EVALUATION REPORT

Making Better Fertiliser Decisions
For
Grazed Pastures in Australia

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CONTENTS

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Executive Summary

The project *Making better fertiliser decisions for grazed pastures in Australia* (BFD) was designed to improve decisions about fertiliser use in the grazing industry for both production and the environment. It began in May 2003 and this phase ends in June 2006.

The project was in three parts:

1. Data collation about fertiliser response rates and the establishment of a national data base
2. The development of a nutrient loss index
3. The development of an education package

Individuals were involved in the project on three levels as:

Members of the steering team
Project staff
Part of the national network.

The objectives of the project were:

1. To ensure that multi-nutrient management within extensive and intensive grazed pasture systems is based on sound production and environmental principles and practices.
2. To develop standard and regionally specific soil test - pasture response functions for phosphorus, potassium, and sulphur fertilisers and pasture response functions for nitrogen fertiliser across Australia using existing data.
3. To develop a framework for consistent interpretation of soil tests from both a productivity and environmental perspective.
4. To review and develop tools that identify landscape characteristics, soils and FMPs that contribute to impacts on the environment, and to integrate ERA tools and nutrient response functions into a decision support booklet.
5. To identify weaknesses in the data sets available and identify specific research to fill these gaps in knowledge.
6. To develop an education package that can be delivered through regional networks to provide fertiliser company advisers, farmers, consultants, and extension officers with more uniform information and greater skills and confidence in fertiliser decision-making bearing in mind both productivity and environmental sustainability goals.

From this evaluation, project staff wanted to know:

- What motivated members of the National Network to become so involved
- About progress against the various objectives
- How information from the data base and the nutrient loss index is going to be use.

Key findings

Involvement by members of the network

- Members of the network became involved because they had data to contribute.
- The subject area was of great interest to them.
- They saw this as an opportunity to make the data available nationally and were proud to have that happen.
- They were pleased to be part of a national network.

They stayed involved because they felt valued because of the data they contributed as well as their input to discussions. They saw that problems were dealt with quickly and efficiently. They appreciated the professional level of project management that kept them all informed.

Objectives

The objectives were achieved in the main or will be by the time the project ends. The timelines for objective 6 (which relates to the education package) have been extended and this is now due at the end of June 2007.

Future use of data base and nutrient loss index

Members of the national network are waiting to find out about how they will use the products from the project because they still want to see the final version of both the data base and the loss index. They remain generally very supportive and enthusiastic but are unsure about how information from the data base will standardise interpretations from soil tests.

Members felt that that the project team may be able to explain how the information from the data base and the index will help with consistent interpretation of soil tests to the project steering team and the national network at the up coming meeting.

Overall value

The comment was made many times that the work on collecting together research data on a national data base was long over due. There were also comments, particularly by members of fertiliser companies, that the development of the nutrient loss index will be very useful to them.

Background

The project *Making better fertiliser decisions for grazed pastures in Australia* (BFD) was designed to improve decisions about fertiliser use in the grazing industry for both production and the environment. Even though many trials had been done in the past, there was not enough collective knowledge about the response of pastures to the various elements that make up fertiliser. There was a need for better tools and data to make decisions in this field. In particular, those tools and data were needed to help to maintain a balance between reducing the risk of nutrient loss to the environment whilst boosting pasture production and groundcover.

The project consisted of three parts:

1. Data collation and interpretation and the establishment of a data base relating to the use of fertiliser for pasture improvement (referred to as the data base).
2. The development of an environmental risk assessment tool/framework dealing with nutrient run-off. (This module resulted in the development of an Index and is referred to here as the ERA Index or nutrient loss index).
3. A communication - technology transfer module.

The project began in May 2003, was scheduled to finish in June 2006 but has been extended for one year. This extension is devoted to the development of educational and communication materials and actions to assist the integration of project outputs into advice to farmers from the Fertiliser Industry and others, such as in DSS programs. This evaluation is a report about impact covering the project to date.

The project was a national project administered by a team from the Victorian Department of Primary Industries at Ellinbank. The original funding was in the order of $4.2m (approximately $1.4m from each of DPI Vic, other funders (Dairy Australia; MLA; LWA; National Land and Water Resource Audit); and in-kind contributions (Industry and other State Research groups. Additional funds (of approximately $75 000) were secured at the end of the second year for the production module when it became clear that the project was behind schedule.

The project team was assisted by two groups:

- A national project steering team who guided the project and provided strategic advice. The steering team included representatives of the fertiliser industry, funding body representatives (DA, MLA, LWA), the project manager and leader for the ERA module, and nominated representatives for State Departments.

- The national network consisted of up to 55 persons experienced in the field. The group was selected across Australia on the basis that they had information and skills to offer (data in particular) and were interested in the process or they were in a position to prime the next users of the data base. The network consisted of approximately 60/40 public-private representation. Of the public group there were slightly more researchers than extension personnel. The private

contingent were principally made up of representatives from fertiliser companies such as Incitec/Pivot, Impact Fertilisers and Hifert,.

Objectives of the project

The objectives of the project were to:

1. To ensure that multi-nutrient management within extensive and intensive grazed pasture systems is based on sound production and environmental principles and practices.
2. To develop standard and regionally specific soil test - pasture response functions for phosphorus, potassium, and sulphur fertilisers and pasture response functions for nitrogen fertiliser across Australia using existing data.
3. To develop a framework for consistent interpretation of soil tests from both a productivity and environmental perspective
4. To review and develop tools that identify landscape characteristics, soils and fertiliser management practices that contribute to impacts on the environment, and to integrate ERA tools and nutrient response functions into a decision support booklet.
5. To identify weaknesses in the data sets available and identify specific research to fill these gaps in knowledge.
6. To develop an education package that can be delivered through regional networks to provide fertiliser company advisers, farmers, consultants, and extension officers with more uniform information and greater skills and confidence in fertiliser decision-making, bearing in mind both productivity and environmental sustainability goals.

Outputs

The anticipated outputs of the project were to:

1. Develop an accessible data base which provides regionally specific production response relationships for N, P, K and S.
2. Establish practical ERA tools (including surrogate indicators) and determine relative priorities for fertiliser management practices.
3. Develop decision support frameworks for identifying environmental risks from fertiliser applications and propose a process for linkage into productivity response functions.
4. Develop an education package for the technology transfer of the results of the project.

Evaluation methodology

The methodology employed for this evaluation consisted of three main elements:

1. Interviews with the Ellinbank project team which consisted of seven persons including the project supervisor, the project manager, communications officer, data collation and interpretation person, environmental risk assessment scientists and the biometrician. Data were collected in two ways:

- Interviews with the project science team leader, the project manager and the communications officer
- Facilitated discussion with all seven members of the project team present.

2. Semi-structured telephone interviews with 16 stakeholders and external contributors to the project (members of the national network and the project steering team). This number consisted of 5 from the national steering team and 11 from the National Network. Of the 11 from the National Network, three were from fertiliser companies and the reminder from government departments of agriculture (7), CSIRO (1).

3. Review of several documents including the project application and the internal evaluation conducted in April 2005.

Three questionnaires were developed: for project staff, members of the national network, and project steering team. These covered the project objectives and the wider impacts and effects of the project. (Questionnaires attached).

Bennett's hierarchy is useful for the incremental measurement of extension projects, especially programmed learning extension projects (technology transfer) and often used by the Department of Primary Industries, Victoria for these. While the BFD project does not represent a programmed learning model of extension it is very like the technology development model where the focus is not so much on learning but on the development of technology – in this case the data base and the NLI (see appendix for a description of the five models). Therefore, some data about learning and involvement were collected.

As well as collecting data against Bennett's Hierarchy, the project staff wanted to know:

- What motivated members of the National Network to become so involved.
- About progress against the various objectives.
- How information from the data base and the nutrient loss index is going to be used.

Results and Analysis

The results are reported under the following headings:

The development of the technology

Involvement

Achievement of objectives

How the data base or index will be used

Indirect benefits

The development of the technology

The development of the technology involved the steering team who made decisions with regard to the direction the project took and solved problems as they arose. The steering team met an average of three times per year. The project also used the help of a national network of researchers. The National Network met three times in the first year, and twice thereafter. The final meeting is imminent. At those meetings, discussions were about the progress in the study, the sources of data, the problems and constraints. The members were asked to contribute data to the project team and timelines were fixed for this process. Essentially the response from the network was enthusiastic, however, active membership waxes and wanes between 35-45.

Project difficulties

Throughout the project a number of difficulties were encountered which meant that it fell behind schedule. These have been well documented in the project review that occurred in April 2005 and do not require a detailed description here, especially since the problems were largely overcome and the project objectives have been met. They are mentioned in brief to assist with a calculation of lessons learnt and to explain the need for the project to be extended to June 2007.

The main problems were:

1. The volume of data received was unexpected. Given the nature of the task, the variable sources of the data and the unique undertaking this could not have been readily anticipated.

2. There was a great deal of variability in the data both as to its quality and form. Some of the problems arose from the sometimes questionable and variable nature of the research that had been conducted. Other difficulties stemmed from the form of the data which did not easily fit within the templates designed for the project and much additional work was required to get it into the correct format before it could be loaded on to the data base.

3. Some contributors from the network were slow to deliver the data. This required additional effort from the project team to follow up with individuals concerned and added to the delays.

4. A team from UNE were employed to construct the data base. They were expert at standardising data but found it difficult to adjust to the different types of data. These problems were compounded because they were not agronomists and had difficulty with terminology and interpretation.

How the problems were dealt with

Ken Peverill was employed as a consultant to manage the project, to obtain the outstanding material and generally to guide the collation and interpretation of the data. He expended considerable effort in following up data contributions and resolving blockages to data contribution. His role is seen by all concerned as crucial to the project achieving its outcomes.

Members of project ream stated that the development of the data base was taken over by the Ellinbank team and the project funds were expanded to allow for additional staff resources to be employed to assist with this process.

What the Ellinbank team took over from the UNE was sound but it required a lot of work to bring it to a point where it could produce the results intended and to meet requirements expressed by potential users when outputs were trialled. In general terms the project was compressed at the end and the project team would have liked more time to test the data base before its release for general use.

The problems with the quality of the data meant the team had to divide it between what was acceptable for input into the data base and what would be used to verify the other results. On many occasions it was necessary to revisit what could be used from some data sets.

Nutrient Loss index

The nutrient loss index did not draw on information from the data base. The researchers here went to the literature and developed a conceptual model and from there an Index which was able to identify the level of risk of nutrient loss on a scale of low, medium and high. The Index took into account factors such as soil type, climate, nutrient management, slope etc and embraced the interaction of these factors. The Index built in rules of thumb that were already in use.

The project team then ran 9 national workshops where the main scientists and researchers were in attendance. Feedback was obtained as to whether the conceptual model and the Index were on the right track. In total the team involved here worked with approximately 90 people across Australia.

What can be improved in future

1. One of the difficulties encountered in this project arose from the outsourcing of the data base to the team from the UNE. Without being critical of them, this experience showed the need to establish very clearly the competency and compatibility of outside teams employed especially when they are responsible for a complex and important part of the project, in this case the data base.

2. In hindsight it would have been preferable to do some sampling of the data before the project proper began to identify the type and quality. This may have allowed for a more realistic timetable to be established and allowed the team to better manage the expectations of the funders and stakeholders.

3. Much of the extra work that had to be undertaken by the project team arose because of the variability of the **form** of the data. In future it may be preferable to establish firm templates as to how the data are to be presented and insist that these guidelines be followed.

Comments about what could have been done better also came from three members of the steering and they were:

Maybe a little more planning up front to avoid having to look for additional funds but this may not have been possible.
Maybe took the project too long to get it up. UNE slowed things up a bit, not enough $$ to make it web based.
Co investment from universities would have been good. For example, have students help with the data base.

However over all from the steering team the comments were:

Been a really good project. The level of partnership and cooperation has been great all get browny points from this and having industry involved is very good.
Given the time and other constraints, the team did a fantastic job. We only ever wanted to find out what the gaps were and got a lot more . Now have the fertiliser companies on side. Could not ask for too much more.

Members of the national network felt that the project was handled very well. None could make any suggestions for improvement and one person stated that he was made to feel he was very much part of a team.

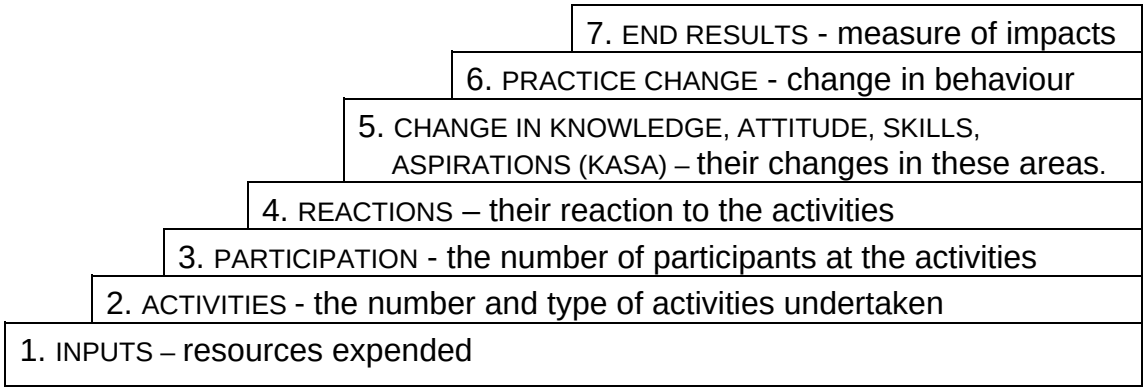
What was learnt

What they learnt was:

- About the NLI ….it broadened my knowledge and competency. Good learning experience
- The understanding of nutrient loss processes across Australia varies considerably, and is often influenced by an individual's local research focus, rather than perhaps taking a broader view to a range of processes. In many respects the FNLI takes this broader view and integrates the range of processes and factors into one place
- Getting consistent response trends, climate soil type. Helped to isolate some of factors involved to explained results.
- The paucity of data in area of nitrogen in particular. There were a lot of studies conducted, but not all had gone through to full publication that could be used efficiently by project. Would be advisable to funders like Dairy Australia to build in a milestone of publishing data.
- There was an awful lot of data not in the general domain in relation to fertiliser decision. Awful lot of gaps if getting down to small units where trials are done and lot of assumptions made.
- Lots of effort required for significant collaborative effort, but necessary for major projects. Also necessity of including extension/communication where relevant. Importance of industry support (e.g. FIFA)
- Surprised at variability of the data and techniques.
- General response curves surprising but will be validated the best that we can. Exposes gaps as well.

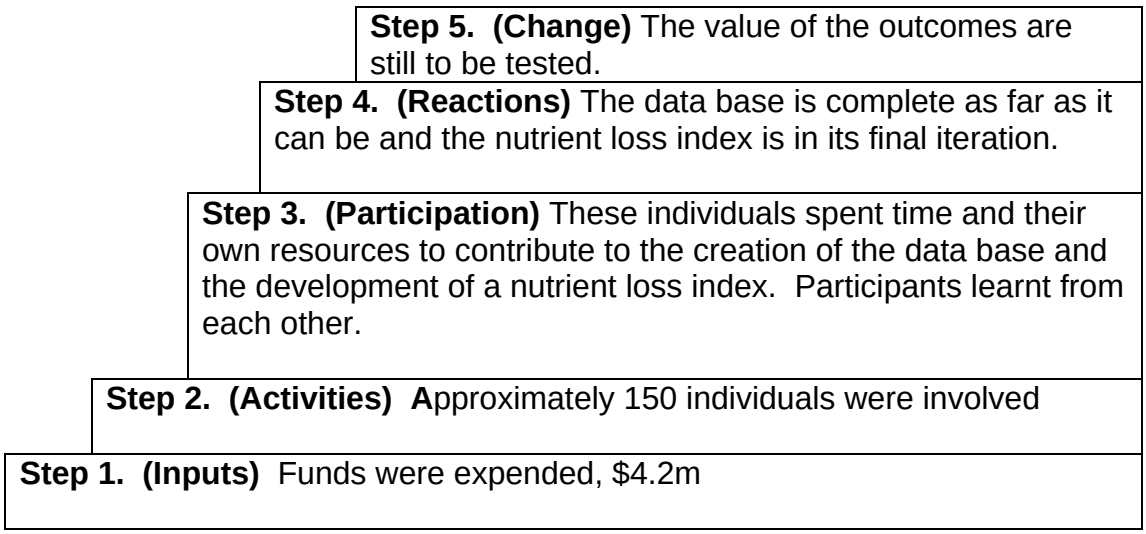
Claude Bennett, while working for the United States Department of Agriculture, developed a hierarchy that can be used to measure incremental progress towards an ultimate outcome particularly with regard to extension. This hierarchy is used extensively in Australia also by departments of agriculture to measure achievement of extension programs.

The hierarchy consists of several steps as seen in the figure below.



(Source: Patton, 1986, p170)

Therefore, with regard to progress against Bennett's hierarchy for this project, comments can be made as far as step 4:



Involvement

The reasons given by individual members of the national network about why they became involved was because:

- Of a long history of research already in that general area (two mentions)
- The subject matter and idea of the nutrient loss index had been an area of research interest for some time
- Of an opportunity to get existing data out into larger network
- Of skill in research in responses to nitrogen
- Co involvement of the fertiliser industry
- Of knowledge that there was a lot of information that had been published but also much that had not and this was a good way to make all that information available
- Fertiliser companies do this sort of research and with the government cut backs rural research there was not a lot of new research taking place and this project was seen as a last chance to get a lot of this information before it was lost before researchers retired.

All of the national network members interviewed felt that it had been a useful exercise and most stated that they enjoyed it. Some definitive comments were:

> Been good exercise and necessary exercise to go through. It will be useful compilation of data and information and a reference for years to come.
> A really landmark project from point of view that it drew on information that had already been researched, it was really needed.

All network members felt that their expectations had been met or were anticipating that they would be met given what they had seen so far. None indicated that they contributed much more than they anticipated. If they did contribute more, they felt it was a very worthwhile cause.

The network members considered that communication with them was very good and felt that they were kept up to date. A comment was made that funds were shared evenly across the regions and partners. They felt that the project team made a real effort to be fair.

Achievement of objectives

Data in relation to the achievement of the objectives has come from the project team and the stakeholders and external contributors. In essence the message has been the same. The objectives have been met and the project has achieved a high level of success. One indicator of the success of the project arises from the workshop conducted in November 2005 at Ellinbank. Here the data base and the ERA index were tested on a group of representative fertiliser companies and both tools were enthusiastically received. Suggestions for improvement from participants in the workshops were included in the final products.

Objective 1 Use of sound production and environmental practices

The objective in full reads:

> *To ensure that multi-nutrient management within extensive and intensive grazed pasture systems is based on sound production and environmental principles and practices.*

Strictly speaking the fulfilment of this objective requires the adoption of technology developed through the project and should wait until the education package has been implemented and until it is clear as to the level of uptake. At this stage of the project however it is possible to say that the pre-condition for adoption is now available through the data base and the index and this objective has been met to the extent possible at this time.

Data base

A data base has been established which can produce the best answers that that can be obtained in the field of its operation. There is no other better source of data. As noted above, the data base has been tested in a two day workshop and the results were enthusiastically received by those attending. This workshop also demonstrated how the data base and the Index can work together.

Comment from a member of the steering team was that while he was not a direct user, the " collated data sets available to all must present far better recommendations to be made".

Comments from members of the national network were that information from the data base should allow the fertiliser industry to predict application rates for farmers or allow industry to check that current practice is best practice. And even though there are gaps in data from the regions and on the relationship between N,P,K and S, the information will still be useful.

Others who have not seen the outputs from the data base for sometime are still waiting to see what will be useful.

Index

Project staff stated that while it is not clear that it will work in all situations it is as robust as it can be given the present knowledge. It is strong in particular areas such as temperate-high rainfall rather than tropical or low rainfall locations. While it may not be perfect it does show the relative risk areas and worked well on testing.

A member of the steering group stated it is:

> Very useful. Issue is to make sure it will be used in a proactive way, to identify opportunity and risk areas for fertiliser application. Biggest issue is getting the users (advisors) to see the value of the tool for them. Unless the users and end user (producer) sees the value, then implementation will be limited, This tool has the potential to make a huge impact in managing and retaining nutrients on site.

Another stated that he thought it was:

> A pretty qualitative measure. Extension agronomists can come up with these criteria from gut feeling but [the index is helpful if they] go along the path of trying to justify their gut feeling. It is a learning tool for inexperienced agronomists.

Members of the steering team were thinking broadly about application of the index particularly and that if

> all farmers in an area are managing land according to the index then there will be an improvement in the condition of the catchment.

Objective 2 standard and regionally specific soil tests

The objective in full reads:

> *To develop standard and regionally specific soil test - pasture response functions for phosphorus, potassium, and sulphur fertilisers and pasture response functions for nitrogen fertiliser across Australia using existing data.*

There is no **one** standard soil test developed from the project however the main soil tests in current use are included. Given the regional and state variability this was always only going to be what the project could achieve.

Objective 3 Framework for interpretation

The objective in full reads:

> *To develop a framework for consistent interpretation of soil tests from both a productivity and environmental perspective and To review and develop tools that identify landscape characteristics, soils and FMPs that contribute to impacts on the environment, and to integrate ERA tools and nutrient response functions into a decision support booklet.*

The feeling by the project team was that this objective has been achieved because all users of the data base will now work off the same set of graphs and there is standardisation along the curve.

Members of the national network and the project steering team need to still be convinced of how this will work as a framework for consistent interpretation.

We recommend that the project team explain the intentions and the implementation of this objective to them at the workshop in Melbourne on the 26 and 27 June 2006. team.

Objective 4 Weakness in data sets

The objective in full reads:

> *To identify weaknesses in the data sets available and identify specific research to fill these gaps in knowledge.*

Project staff indicated that it became apparent early in the project what data were not sufficiently reliable to be included in the data base. It is also apparent when the data base is interrogated that many regions were not well

covered and that not all relationships between N, P, K, and S had good information.

However, there was endorsement from national network when asked how do they know that the information on which the data base and the index were developed was soundly based. They relied on the:

> Capability of the research teams
> The technical skills of scientist that put data base together and have listened to UNE and others so that it is robust statistically.

They felt that:

> [The] data base good confidence. There is a variance around the results anyway. Having heard the history and quality control [were] led to believe that quality is good.

Other comments were:

Steering team

> Just because there are gaps, does not suggest they must be addressed, but glaring holes may need attention.

National network

> Response curves at paddock level may not have the level of detail for amalgamation for broad scale environmental outcomes.

Objective 5 Education package

The objective in full reads:

> *To develop an education package that can be delivered through regional networks to provide fertiliser company advisers, farmers, consultants, and extension officers with more uniform information and greater skills and confidence in fertiliser decision-making bearing in mind both productivity and environmental sustainability goals.*

During the project the concept of "educational package" was expanded to include the use of project outputs in existing industry DSS systems and advice, recognising that the fertiliser industry, private farmer consultants and state extension programs already include elements that cover these matters and that a standalone "new" package would not usefully compete with these activities. As noted earlier the project has been extended to allow for this aspect of the project to be completed. The outputs of the project so far regarding the data base, the index and manual provide the basis for this part of the project to be completed satisfactorily. The data base and index have been tested and modified and are ready for use by the target audience, namely extension personnel in the fertiliser and government extension circles. Planning is well underway with a proposal to heavily align the education package with the Fertcare program which should see strong adoption by the fertiliser industry. Another audience that has been identified are Catchment Management Authorities and EPAs

A comment from a funder on the steering team is that they will help with fact sheets. Another steering team member stated that the "impact the project has

made" has been in assembling the technology and the managerial level of the potential end users.

Further comments from the steering team were:

- Nutrient loss tool has a lot of potential, and should not be limited to advisors having a 'black box'. Need to drive producer awareness of the opportunity to demand the technology,.
- Communication impact could have been developed in sowing the seeds of what is coming, developments to date, engaging end users etc.
- The focus now must be getting uptake of the technology by the advisors and creating a "pull through" by the producers. These must be undertaken together.
- Maybe connect with Healthy Soils project in LWA and connect with CMAs.
- Build in opportunities for application that allows customisation. Some of the end users will want to create a competitive edge by using this material, Determine the "value proposition" for each (delivery) group, and ensure that is it delivered, as against just a technology package.

How the data base or index will be used

Comments for this section came from the national network and they were:

Data base

- At the private advisory level in fertiliser use
- For nutrition research if the organisation is still involved, have a network of extension people and should be a great help to them
- Will be extensively used, to develop more simplistic decision support tools, for farmers
- To build awareness of nutrient loss and relationships with production
- in research
- Regional response curves and use those if asked for advice on critical soil tests and fertiliser rates
- Not a lot of Tasmanian data but once populated will use. Some Victorian data useful.
- Very useful core ref material that researchers in this area will go to before starting work.

Nutrient loss index

- Working on a similar thing for sugar and not as generic but has not been able to keep up to date with final product and may use it when knows more about it.
- Index org have intensive livestock ext staff and will be big help to them.
- NLI more a farm tool.
- Its main users are going to be policy people and regulatory people. Potentially disadvantageous to farmers.
- Database will be used, will be basis for most of our future work to do with nutrients. Work that I do sits one step behind Loss index, so it won't be informing us, we will be informing it.
- Data base as a ref and in some cases use in models.
- Fertiliser companies more than DPI research.
- NLI biggest problem there is time to use it. Advisers not get paid for advice. Latest version is a lot quicker.
- NLI that is the big one and most important one that is going to be used in research in the Farmlets.
- I would like to be able to compare the index spatially with other nutrient loss risk approaches to see how well other approaches correlate with the predictions of the index. Additionally at a small subcatchment scale I would like to compare different risk indices predict measured water quality.
- FIFA they seem to have a genuine commitment to environmental side of fertiliser application.

- For the production market but more for environmental programs such a DairySAT and other self assessment tools.

When asked if they will be used together, a small proportion of respondents asked “why not?” But most still separated the uses between production and the managing natural resources.

Indirect or unintended benefits of the project

There were significant benefits arising from this project and at various levels. They have occurred for the fertiliser industry generally, at the project team level and personally for the individuals involved at Ellinbank.

Industry wide general benefits

The collective response from the national network and the steering team about what the legacy of the project will be was:

- a national network of contacts with other researchers
- the database – as long as it is continued and expanded
- soil- nutrient responses to be used by advisors
- nutrient loss tool – as long as it is used
- hopefully improved advice from fertiliser reps to the farming industry on application rates under different conditions across Australia and reduced nutrient run off into environment
- more profit for farms

.
The beneficiaries of the project will be:

- Fertiliser advisors, and if the delivery and uptake is successful, the producers (from a production and resource management perspective),
- Future R&D researchers who are working on soil- nutrient responses, DA, LWA, MLA on considering investments in this area
- Across the board research community having their data

Comments from project staff

1. Overall the greatest benefit of the project has been the increase (or in some cases the establishment) of networks in this area. The networks have been across and between sectors and between individuals. These have resulted from membership of the NN and the Steering Committee and from the attendance at the workshops run as part of the development of the environmental index.

2. The involvement of the fertiliser industry. This began somewhat warily but increased significantly as the project progressed. The interest increased especially when the usefulness of the data base and the Index could be demonstrated. One marker of the level of interest by the fertiliser industry is the appointment of a representative from that sector to the Steering Committee for the remainder of the project.. This enthusiasm and dialogue augers well for the roll out of the education package.

3. The variability in the quality of the data has lead to the development of an experimental protocol for soil research.

4. The project has substantially increased the learnings for all involved. Apart from their impact on the fertiliser industry, the data base and Index should provide good educative tools for CMAs and EPAs.

Benefits for the project team

1. The seven members of the Ellinbank team worked very well together. The range of skills and experience were well utilised and a cooperative and participatory ethic was adopted. Older members were stimulated by the zest of the younger. The team was able to adapt to the challenges posed and to deliver against the objectives.

2. The successful completion of a significant nationwide project has no doubt enhanced the reputation of those involved. Already a new project has been established which has its genesis in BFD. The fact that a project involving 19 stakeholders could be satisfactorily completed has shown the project team new possibilities for large projects of this type.

3. The project was valuable for the project team because it required them to look beyond Victoria and beyond dairy. It broadened the focus and increased the knowledge of the team members.

For individual members of the project team

A range of benefits were identified by the project team members. These included:

1. New knowledge for almost all concerned. This included increased knowledge of grazing systems, the role of “soft systems science”, the complexities and range of factors involved in both the production and environmental aspects of the study. For those more experienced in the field the project confirmed or reinforced knowledge.

2. Taking on new processes such as the facilitation of workshops was seen to benefit those not already experienced in this art. The challenge of operating “out of the comfort zone” opened new possibilities.

3. It is possible to manage a complex nationwide project.

4. Establishment of individual contacts and networks.

Conclusion

All individuals interviewed for this evaluation responded enthusiastically to this review. They recognised the project’s worth and the potential usefulness of its products. Many comments were made about how well the project was managed and Ken Peverill and Cameron Gourley were singled out here. Project members mentioned on more than one occasion that they were made to feel like members of a team and that their data were valued.

Problems were dealt with quickly as they arose and communication about progress was excellent.

Two salient aspects of this project for the evaluators were that:

1. The work to collate this data on a national data base was timely, much needed and will be very useful.

2. The work with regard to the nutrient loss index provided many individuals involved with the project with new knowledge and they are anxious to take the work out to relevant audiences.

References

Patton, Michael Quinn 1986, *Utilization-Focussed Evaluation,* Sage Publications, Newbury Park, California.

Appendix 4A Extension models

What works and why in extension

Based on a review of over 50 recent and current extension projects from around Australia across agriculture and other fields, five extension models have been identified and best practice guidelines developed based on these models. The five extension models are as follows:

facilitation
technological development
training
information
consultant.

ABOUT THE MODELS

Five models were identified based on their underlying philosophies and the way they operated. They are:

The facilitation model, where participants increase their own capacity in planning and decision-making and in seeking their own education and training needs based on their situation. Groups may undertake their own research. The project will often provide or fund a facilitator to help groups define their own goals and learning needs and to help them realise these.

The technological development model, where individuals work together to develop specific technologies, management practices or decision support systems which will then be available to the rest of the industry or community. It often involves local trials, demonstrations, field days and on-site visits.

The training model, where specifically designed training programs and workshops are delivered to targeted groups of landholders, community members, government personnel and others to increase understanding or skills in defined areas. These can be delivered in a varietyof modes and learning approaches.

The information model, where individuals and groups can access a broad range of information from a distance at a time that suits them. It can be based on a website, information centre or other centralised locations.

The consultant model, where a mentor or consultant works over time with an individual or community to improve their managerial, technological, social or environmental situation.

Coutts, J.; Roberts; K; Frost, F; and Coutts, A. 2005. *Extension for Capacity Building: What works and why?* Rural Industries Research and Development Corporation; Kingston, ACT

Appendix 4B: questionnaires

Questions project staff

Standing back from the project, what are the parts that

What worked really well for you?

What you would not repeat?

What would you keep but improve?

What will be the long lasting legacy from this project?

Who will benefit the most?

How do you know that the information you have on multi-nutrient management within extensive and intensive grazed pasture systems is based on sound production and environmental principles and practices?

To what extent have you developed standard and regionally specific soil test - pasture response functions for phosphorus, potassium, and sulphur fertilisers and pasture response functions for nitrogen fertiliser across Australia using existing data?

Do you now have a framework for consistent interpretation of soil tests from both a productivity and environmental perspective?

How confident were you that you could identify weaknesses in the data sets available?

Have you identified specific research to fill these gaps in knowledge?

Have you developed an education package that can be delivered through regional networks to provide fertiliser company advisers, farmers, consultants, and extension officers?

How will you know if it is more uniform information and given them greater skills and confidence in fertiliser decision-making bearing in mind both productivity and environmental sustainability goals.

What do you want to know from others involved in the project that will help you decide its level of success?

National Network

This is for people who contributed data to the project and who were part of on going discussions about the data base and the index.

Preamble: *In the period 2002 to now you have been part of the project* ***Making better fertiliser decisions for grazed pastures in Australia.*** *We have been asked by the manager of the project to carry out an evaluation of the project and would like to ask you some questions about your involvement and expectations. The interview will take about 20 minutes. Even though we keep your comments confidential, given the fairly small numbers of people responding to this survey, we cannot guarantee that the sentiments of your comments will not be attributed to you.*

Are you still happy to respond to some questions?

1. Tell me about what you feel generally about your involvement with the project "Making better fertiliser decisions for grazed pastures in Australia"

2. What motivated you take part in the project?

3. What aspects of your involvement with the project worked really well?

4. What would you improve if you were running the project?

5. How many other people from your organisation were involved with you in this project? (for example helped you collect data or discussed the data base or the nutrient loss index)

6. What were your major learnings from this project?

7. Did you receive what you expected from this project?

   1 2 3 4 5

   No not really Exceeded my expectations

   Please comment

8. Did you contribute what you expected to this project?

   1 2 3 4 5

   No not really Exceeded my expectations

   Please comment

9. How has your involvement with the project influenced the way you think about taking part in a national research project?

10. How has your involvement with the project influenced the way you think about the use of fertiliser ?

11. How has your involvement with the project influenced the way you think about nutrient loss?

12. How are the outputs from the project likely to be used by you or your organisation, for example:

    1. How is the data base likely to be used?

    2. How is the fertiliser nutrient loss index likely to be used?

    3. Are the two likely to be integrated in the work that you or your organisation does?

13. What has been the legacy for you of being involved with this project?

14. Do you have any other comments to make about anything to do with the project?

THANK YOU FOR YOUR CONTRIBUTION. YOUR COMMENTS WILL BE MOST HELPFUL FOR THE PROJECT STAFF.

project steering team

Preamble:

*In the period 2002 to now you have been part of the project **Making better fertiliser decisions for grazed pastures in Australia**. We have been asked by the manager of the project to carry out an evaluation of the project and would like to ask you some questions about your involvement and expectations. The interview will take about 20 minutes. Even though we keep your comments confidential, given the fairly small numbers of people responding to this survey, we cannot guarantee that the sentiments of your comments will not be attributed to you.*

Are you still happy to respond to some questions?

1. Can you describe for us what you did with regard to the project as a member of the steering team?

2. Standing back from the project, what are the parts that:

   - What worked really well?

   - That could be improved?

3. What will be the long lasting legacy from this project?

4. Who do you think will benefit the most?

5. How do you know that the information is sound that forms the basis of:

   - the data base
   - the index?

6. What are your thoughts about the usefulness of the outputs from the data base to predict pasture response functions (within a useful range) for phosphorus, potassium, and sulphur and nitrogen fertilisers across Australia using the existing data?

7. What are your thoughts about the usefulness of the index to highlight high, medium and low risk areas with regard to nutrient loss across Australia?

8. What comment can you make with regard to a framework being available now for consistent interpretation of soil tests.

9. With regard to advisers now being able to provide consistent advice about fertiliser use:

   - Will the outputs from the data base be useful?
   - Will the index be useful?

10. What comment would you make with regard to the weaknesses in the data provided?

    - For the data base?
    - To develop the index?

11. The education package is still to be developed and will de delivered through Fertcare as one option, however, what suggestions would you like to offer to its developers so that can be delivered through regional networks to fertiliser company advisers, consultants, and extension officers?

12. Are there any other comments you would like to make abut this project that will help the project staff understand the impact their project has made?

APPENDIX 5

Better Fertiliser Decisions Final National Network and Project Steering Committee Joint Workshop

At the final joint workshop of the Project Steering Group and National Network, held in Melbourne on the 27th and 28th of June 2006, a discussion session was held to gain feedback from project participants. Small group discussion was held on the following questions:

1. Arising from the BFD project, what opportunities can you see for future research?
2. Arising from the BFD project, what might change about fertiliser use?
3. How might you use the BFD database and Farm Nutrient Loss Index? Could you see them being used together? In what way?

The following views were expressed:

Future opportunities

- Undertake validation of sulphur test with consideration for sampling depth
- Catchment scale links to FNLI
- Central input/database for FNLI
- Account for rainfall and other limiting nutrients in determining critical values to tighten the range of critical soil test values in soil types
- Linking nutrient loss to fertiliser budgeting
- Calibration of Colwell P against Phosphorous Buffering Index
- Relationship between soil texture and Phosphorous Buffering Index
- Check the value / reliability of pooling trial data with variable features (species, moisture) into one common critical Colwell value
- The production / environmental consequences of “frequent” NPKS application on pastures
- More database analysis – disaggregation; using PBI by re-analysis of samples or checking against soil archives
- Link agronomic with environmental information
- Review of Critical level for State / Region
- Development of standardised nutrient testing
- Use database to verify other models (eg “Grassgrow”)
- More Nutrient Loss validation
- Review Nutrient interactions; timescale issues (Ginnindera examples)
- Link both production database and Loss Index to economic farm model – economic analysis of fertiliser use
- Examination of fate of N and S; pasture/crop systems use of nutrients
- Relationship between animal production studies vs pasture response studies

Influences on future fertiliser Use

- Potential for better adoption of BMP for more efficient fertiliser use
- Increased awareness of soil test values vs critical values; paddock variation affection nutrient loss; over-riding environmental considerations
- Move toward standardisation of critical ranges – improving confidence and credibility of industry and lower “overuse” and “under-use” of fertilisers
- Variable applications on pastures – eg using spreader instrumentation; identifying urine / dung patches

- Increasing effort to look at K and trace movement (now happening in crops, pasture next)

Utility of outputs and products from the BFD project

Database:
- Use to identify future research (eg CSIRO) and verifying recommendations
- Use to highlight critical ranges (single figure detrimental) and regional differences
- PDF static display of analysed data will be used than the database – needs detailed explanatory notes
- For individual interrogation (by advisors; researchers)
- Mid / top users will use it to prepare regional extension material
- Expand to incorporate cropping

FNLI:
- Readily promoted to end user
- Education tool for Fertiliser staff / dealers, CMA staff, whole farm planning courses – incorporate into existing (and new) extension products
- Communication tool for “Greener Pastures” project
- Hot spot mapping for farmers
- Future justification of “farming for use” tool
- Could be used in DA “Farm Change program” and Dairy SAT
- In Fertcare and EMS
- Widespread use in fertiliser decisions – web based and / or advisors

Use together:
- If database results can be incorporated into FNLI
- Not necessary that they get used together