

# Advances in the development and use of interactive Decision Support Systems for agri-businesses: a case study from a major fertiliser manufacturer in Western Australia

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## Abstract

CSBP Ltd is the leading fertiliser manufacturer in Western Australia (WA). It is using a computer-aided decision support system (DSS) to assist fertiliser advisory services (“NUlogic®”). Previously a PC-based programme was used by agronomists (users) for the interpretation of soil and plant nutrient analyses and generation of customised fertiliser recommendations. However, the objective for the recent advances in the DSS was to include additional usage for business management and to connect the DSS to farmers and the laboratory conducting the analyses. The DSS is now an online system. Cloud computing stores and automatically backs up large datasets. A smart division of two websites of the same DSS, one “live” stage and one “testing” stage, allows for effective user acceptance testing (UAT) and software training of new advisors without interfering activities on the “live” stage. The underpinning algorithms of agro-economical models are written in a simple programming language, Optimisation Modelling Language (OML). Model updates and improvements in the OML go live after testing and are then instantly available to all users. An analytical testing platform (ATP) uses an application programming interface (API) to connect with the models, other interpretive criteria, comment lists, non-model related inputs, the order of outputs on reports etc, making it cost-effective, flexible and quick for the data analyst(s) to update versions. In addition, the ATP itself connects with the laboratory, farmers and DSS users. Consequently, this DSS allows monitoring of recommendations from DSS users in real time to (1) identify those that require more training and to (2) ensure recommendations comply with Australian standards from the national Fertcare program that audits the quality of advice given to maximise farm productivity, environmental care and food safety. The DSS also logs user’s activities, keeps a record of all current and retired models/model packages with the option of refreshing a retired model/model package, gives full transparency of generated data from recommendation reports for business decisions and offers better software support to users. These advances in the development of the DSS enhance data security, integrity, geo-referencing via mapping capabilities and user-friendliness, offer ease of communication to all users and access to other data storage tools (i.e. farm planning, libraries). Capturing additional data while users are making a fertiliser recommendation is useful to improve market intelligence, forecasting, trend analysis, benchmarking and inventory management. It can be reasoned from a software engineering perspective that this example of a DSS for a fertiliser manufacturer in Western Australia could be easily transferred to other agri-businesses and government agencies world-wide, thereby impacting on the success of businesses and extension services.

## Key Words

DSS, online, OML, ATP, API

## Introduction

There are several important considerations for the development of the DSS. Firstly, the data modeller from CSBP maintains and develops the underpinning equations that give soil and plant nutritional advice. As farming practices, laboratory methods or varieties with different nutrient uptake efficiencies change or new relevant field research results emerge, the models are updated in a flexible and cost-effective manner. Thus, the architecture or software build for the DSS should consider model development (Figure 1), which continues rapidly with increasing usages and number of users who can suggest improvements.

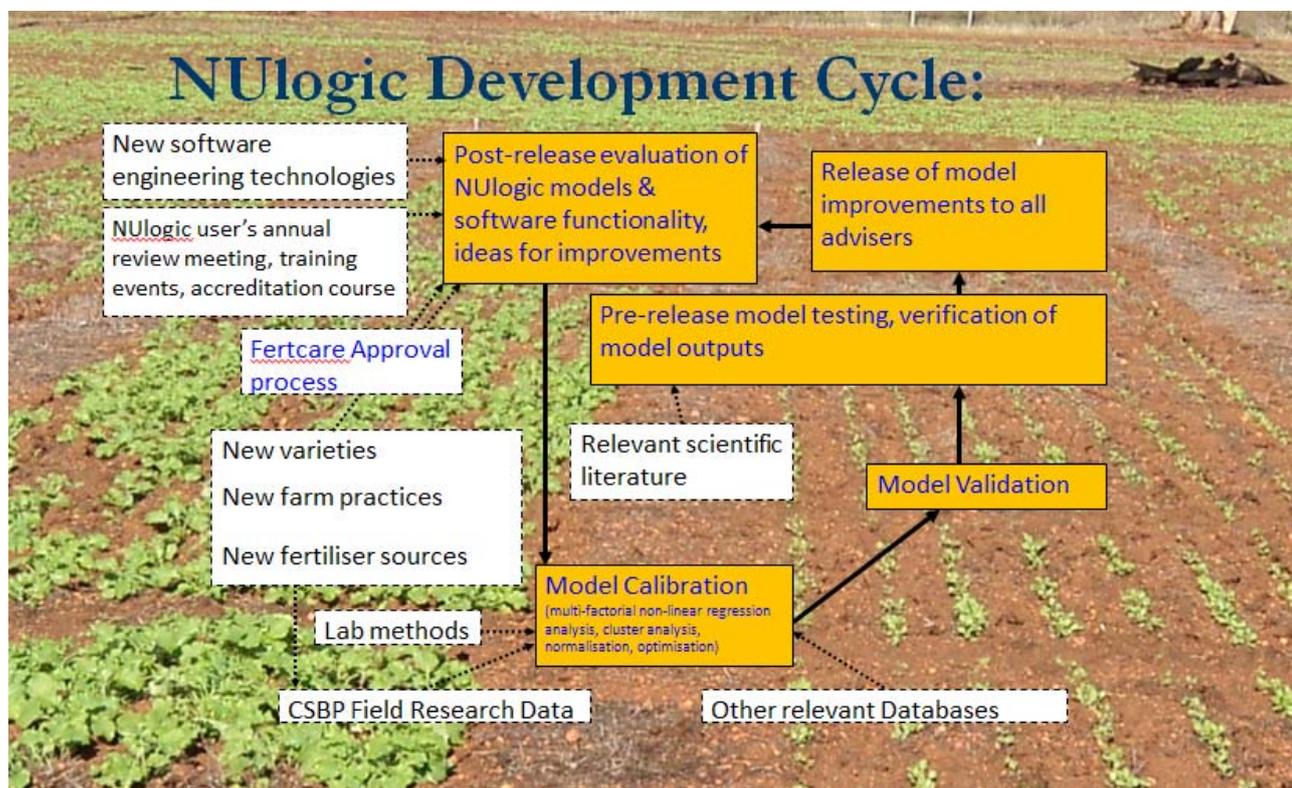


Figure 1: Development cycle for the DSS agronomy models used by CSBP.

Another important element of the DSS is to include changeable and non-changeable inputs. The models are flexible enough to be adjusted by the advisor's local knowledge (fine-tuning target yield, summer rainfall, nutrient uptake efficiencies, rotations, farmer's risk profile, best suited or preferred fertiliser source, placement, timing and rate), including economic factors (costs, prices, interest rates, number of months for a loan), without being able to directly manipulate the analytical data and the calibrated biological response curves. Stone and Hochman (2004) argue for such subjective adjustments, because "what appear to be technical and quantitative management 'problems' often involve social, qualitative and subjective processes and 'solutions' that DSS are not well-equipped to consider". While there are other crucial considerations (e.g. user friendliness of the software, data security, further data interrogation, ease of improving the algorithms for the models), the choice of what variables are over writable remains an essential element of the DSS.

The DSS needs to be able to correctly execute NUlogic's agronomy models, which are among the most sophisticated in Australia. Recommendations from soil models are in its first instance using a sufficiency approach, overlaid with the economics to give for example N, P and K rates that achieve the maximum gross margin for the grower. The DSS user can apply other approaches, such as a budgeting, sensitivity or a replacement approach, either in combination with the economic optimum recommendation or as an alternative. The NPK interaction is extending the widely accepted and experimentally proven theoretical framework from Liebscher (1895), Mitscherlich (1909, 1956) and Baule (1917). Crops like grain cereals, oaten hay and canola display a genuine NPK interaction, which is used to simulate gross margins on the strength of quantifying the possible effect of one nutrient limiting the efficiency of the other two. It is to ensure that overestimates of economic optimum rates are avoided, which can occur when only considering single nutrient response curves or double nutrient response surfaces. In Australia this is the only DSS that has the three macro-nutrients (NPK) interacting in a model and thereby reflects more realistically the situation in WA. Modelling, including reverse modelling, is deterministic and based on multi-factorial non-linear regression analysis and cluster analysis. Recommendations and qualitative interpretations from soil models are calibrated against the actual, target yield and various interrelated soil chemical, crop and economic factors. Variable rates can be compared with blanket rates in terms of opportunity costs. Plant models are calibrated against a relative yield, which can be translated back to actual yields. This can be done using a model to calculate a water-limited potential yield from which to deduct the percentage of relative yield decline due to the most limiting nutritional deficiency. Plant tissue testing is a good monitoring tool to identify nutrient deficiencies before symptoms appear and yield loss occurs. The NUlogic interpretation is also diagnostic and prognostic and helps to define the best timing of nutrient applications, given weather conditions and plant developmental stage are favourable for an application. Nutrient uptake from soil is evaluated in terms of the demand (i.e. of the whole shoot) at the time of sampling that would give a maximum yield at the end of the season. Again, this depends on many interrelated factors such as plant age, plant weight, nutrient interactions, geographical locations and yield potentials. This unique method of interpretation has been pioneered by Southern (1985) in WA and does not require the adviser to sample at a specific plant stage, because it is not related to one critical value but to a curve containing many critical values in relation to maximum yield throughout plant development.

Furthermore, the DSS has to interpret a high volume of sample results (approximately 80,000 samples x 10-26 results per sample) and therefore should be capable of handling a large amount of data, which would have to be

stored and logged. In addition, independent audits of the DSS require a rigorous system of quality testing and of delivering current best management practices. Hence, CSBP conducts field research trials independently, but also collaborates with government research organisations (regional and national) such as The Department of Agriculture and Food Western Australia, CSIRO and various universities. Currently up to 200 000 samples per annum are analysed Australia wide at the ASPAC (Australasian Soil and Plant Analysis Council) accredited CSBP Soil & Plant Laboratory. About 100-140 accredited and in-house trained agronomists are using the NUlogic system in WA to annually generate recommendations from about 50 000 – 70 000 soil and 10 000 – 15 000 plant samples. The feedback from those advisors, in addition to CSBP’s field research trial data and the independent Fertcare audits, contribute to update/refine/improve the DSS (Figure 1) to ensure it is always updated and gives the best possible advice for fertiliser management practices, thus improving CSBP’s NUlogic extension service.

## Methods

The architecture of the DSS is complex and involves giving access to various people from CSBP and the software provider “Agworld” (Figure 2). The workflow of generating a recommendation is as follow: the DSS user receives notification from the laboratory that analysis results have been sent to the ATP. Once the DSS user runs an appraisal, the relevant agronomy models will be called and determine what inputs (parameters) are required prior to interpreting the results. The DSS user then selects and/or overwrites the parameters before submitting those inputs to run the models or model package. Agronomy models are embedded in the Maintenance and Development Application. Outputs (decisions) are then sent back to the ATP via the API. Approved appraisal data is returned to the Maintenance and Development Application of the DSS for further interrogation.

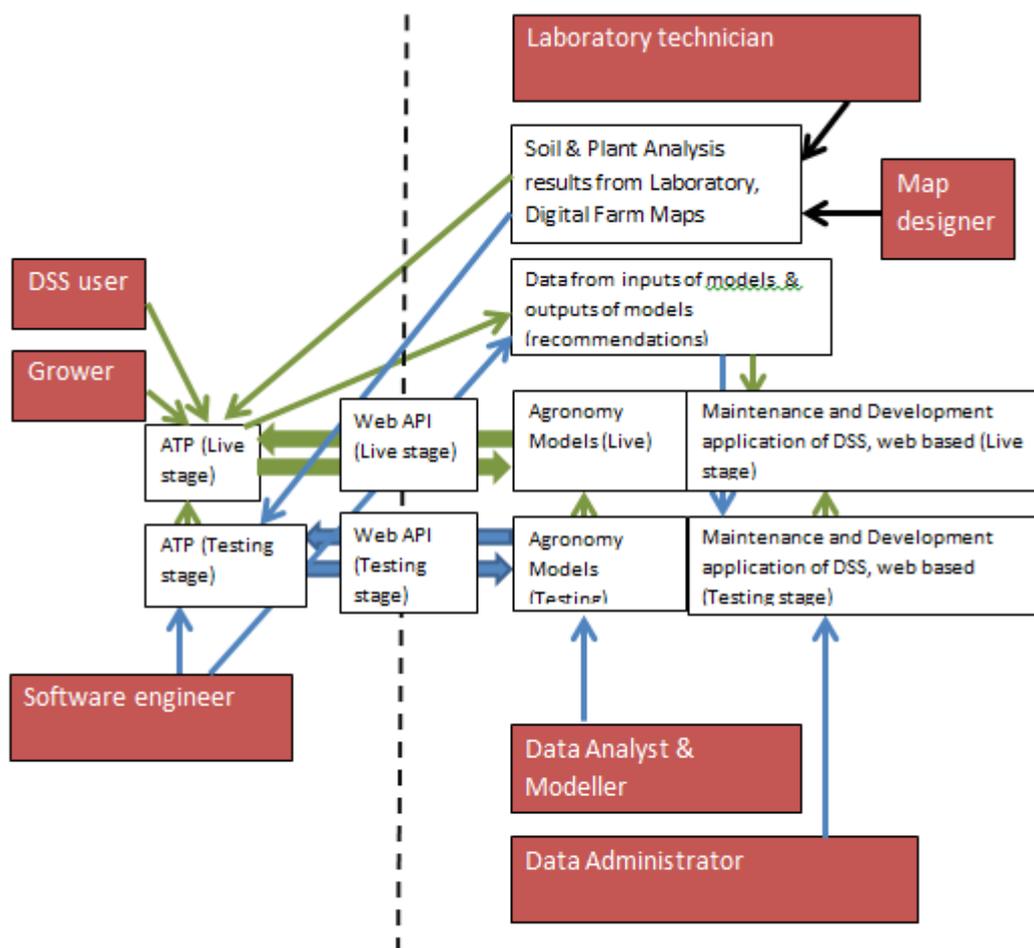


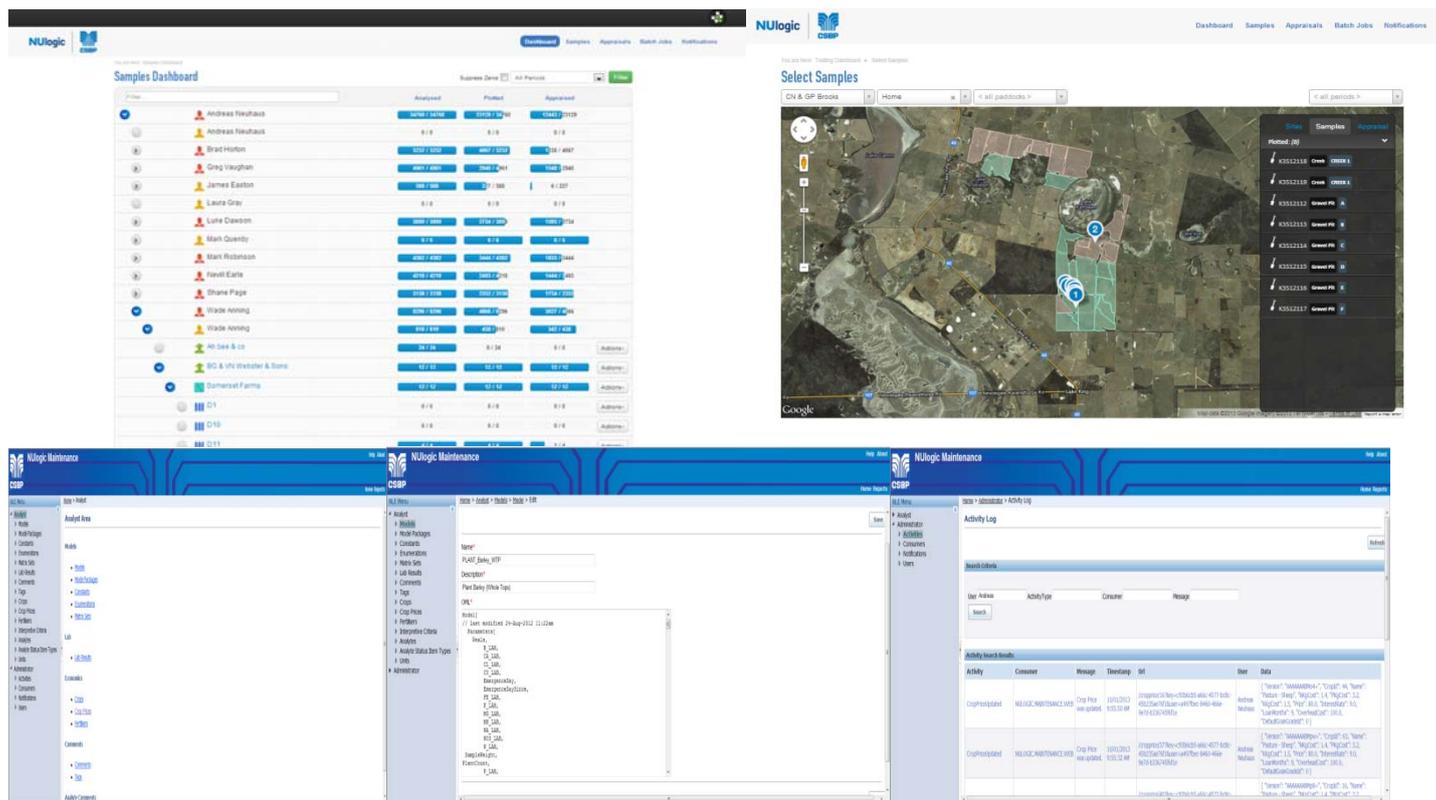
Figure 2: Front-end (left of dashed line) and back-end (right of dashed line) of the DSS showing the dataflow for the live and testing version using two separate ATP's, API's (conduits between calling model inputs and outputs) and Maintenance and Development Applications with their agronomy models embedded.

Different programming languages are used for the various compartments of the DSS architecture. The major system components are: Raven, Microsoft SQL Server, Microsoft IIS Web/Application Server, NHibernate, JRuby, Microsoft Solver Foundation, an open source Dependency Injection tool, Microsoft's latest Model-View-Controller (Razor MVC3) abstraction library, WESCEF Core authentication and other services, Newtonsoft JSON, C# and JQuery Javascript Library.

## Results

Since launching the DSS in September 2012 and as a result of using an online cloud based DSS and the way it was designed, it is now possible: (1) to automatically back up data from all users in one location, (2) to amalgamate information for benchmarking and trend analysis, (3) to link other software systems from other providers to DSS users, growers or the laboratory, (4) to easily communicate to all users, (5) to have clear ownership of Intellectual Property of compartments or modules of the DSS, (6) to efficiently and rapidly update models at low costs, (7) to instantly grant or deny access to the DSS for users without having to issue a licence or wait for a licence to expire, (8) to connect to the DSS from any PC where internet access is available and (9) to log any activity from users as well as (10) to audit recommendations randomly from users at any time to satisfy Fertcare System Accreditation in Australia. The experience of using this DSS revealed so far only one limitation, which is the connectivity of the internet in remote areas and hence the speed of generating a recommendation. In the future this problem is expected to be overcome by better technologies for faster data transfer.

Examples of the various compartments of the DSS architecture are given below (Figure 3a-g).



Wilgrup - Middle and West

Trading Name: RG & AP Wheatley  
 Farm: Wilgrup  
 Date: 01 Feb 2013 08:37  
 Accredited Advisor: Dan Glover  
 Phone: +61897249836  
 Mobile: +6143359325  
 Email: dan.glover@csbp.com.au  
 Sample Type: Soil  
 Crop / Pasture: RYEGRASS  
 Interpretive Criteria: RYEGRASS - WA



Interpretation Results

	SITE: MIDDLE A (184) Middle (184) ID:88881010 Ptn: A	SITE: MIDDLE B (184) Middle (184) ID:88881011 Ptn: B	SITE: MIDDLE C (184) Middle (184) ID:88881012 Ptn: C	SITE: WEST D (184) West (184) ID:88881013 Ptn: D	SITE: WEST E (184) West (184) ID:88881014 Ptn: E	SITE: WEST F (184) West (184) ID:88881015 Ptn: F
pH (1.5 soil)(C12) (4B1)	4.7	4.8	4.8	4.7	4.8	4.4
pH (1.5 soil)(41) (4A1)	5.4	5.3	5.6	5.7	5.5	5.4
AI (C12) (mg/kg)	2.5	3.0	1.8	1.5	1.4	3.0
EC (1.5) (dS/m) (3A1)	0.064	0.102	0.379	0.095	0.078	0.077
Organic C (2000) (N) (8A1)	4.90	3.71	4.45	4.55	2.97	2.62
N2O-N (KCl) (mg/kg) (7C14)	28.3	16.0	38.6	11.7	21.2	5.1
NH4-N (KCl) (mg/kg) (7C14)	2.6	2.0	25.4	2.3	1.2	3.7
P (Colwell) (mg/kg) (9B1)	56	29	13	22	20	8
PM-CaP (3Ka)	389	145	412	167	178	119
K (Colwell) (mg/kg) (18A1)	85	29	74	78	119	22
S (CaCl2) (mg/kg) (15D1)	12	7	15	7	12	9

User Inputs

	SITE: MIDDLE A (184) Middle (184) ID:88881010 Ptn: A	SITE: MIDDLE B (184) Middle (184) ID:88881011 Ptn: B	SITE: MIDDLE C (184) Middle (184) ID:88881012 Ptn: C	SITE: WEST D (184) West (184) ID:88881013 Ptn: D	SITE: WEST E (184) West (184) ID:88881014 Ptn: E	SITE: WEST F (184) West (184) ID:88881015 Ptn: F
Target pasture yield (t/ha)	8	8	8	8	8	8
Yellish	heavily loam	heavily loam	heavily loam	loamy sand	loamy sand	loamy sand
Colour	Dark Brown	Brown	Brown Gray	Brown Red	Brown Orange	Brown Yellow
Ground (%)	15	5	5	25	5	5
Sample depth (from)	0	0	0	0	0	0
Sample depth (to)	10	10	10	10	10	10
Legume (%)	10	10	10	10	10	10
P (0-10) (kg)	120	120	120	120	120	120
P (10-20) (kg)	3	3	3	3	3	3
K (0-10) (kg)	145	145	145	145	145	145
Interpret rules (%)	9	9	9	9	9	9
Loam (months)	9	9	9	9	9	9

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Figure 3a-g: Dashboard (a), plotting samples to sites (b), Maintenance and Development Application (c), Agronomy models in OML within the Maintenance and Development Application (d), Logged activities (e), example of the first page of a completed appraisal (f) and Appraisal Index (g).

Conclusions

This DSS includes additional usage for business management and connects the DSS not only to users, but also to farmers and the laboratory. Furthermore, the compartmentalisation of the DSS allows to add or link more software systems and to add new models and interfaces, which can now be done in a more time and cost efficient manner compared with the previous desktop version. However, the slow time to load the pages remains a challenge and an on/offline functionality could maybe improve the DSS in remote places of WA.

Apart from adding new models and new interfaces for calculators, the use of decision support tools that could include geospatial data analysis using gps based data sets could be a useful addition for growers to carry out customized scenario planning based on their individual paddock variability and trends. Future plans for this DSS are also to make the interactive map interactive. Thereby colour coded analyte maps can be generated using the status colours. Furthermore a calendar/map could be generated for users that records and displays previous, tagged recommendation comments, to show i. e. recommended plant tissue testing at certain times during the season in certain paddocks. The map could also be used for displaying interpreted soil moisture data, biomass, yield or even fertilizer applications.

In summary, this compartmentalized system of a DSS could be applied to other agri-businesses or government agencies to improve extension services by making new research outcomes quickly available to all users at lower costs.

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