FINAL REPORT

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CSO194

Nutrient balance of a typical wheatbelt farm in WA and impact on soil properties

PROJECT DETAILS

PROJECT CODE:	CSO194
PROJECT TITLE:	NUTRIENT BALANCE OF A TYPICAL WHEATBELT FARM IN WA AND IMPACT ON SOIL PROPERTIES
START DATE:	01.07.1998
END DATE:	30.06.2002
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Summary

Old or Archival Reports (Projects that concluded in 2007 or earlier)

Conclusions

Analysis of farm records and modelling uncovered imbalances in K, Mg, P and N. Chemical analysis of matching paired bushland and cropping sites confirmed the anticipated impact of this imbalance on soil nutrient reserves and soil properties. The decline in soil K and Mg is easily reversible with fertiliser application. The use of these elements in fertilisers is expected to be environmentally beneficial.

P accumulation is potentially environmentally harmful due to potential contamination of water bodies, as soil test values and P loading on soil surfaces exceed critical values. The opportunity is to both match P supply with requirement and to develop technologies to allow plants greater access to the P bank.

The pasture phase plays an important role in the supply of N to the farming system. N depletion occurs as a result of the reduction of the pasture phase under intensive cropping. The N imbalance under intensive cropping may be linked with the long term decline in grain protein.

Nitrate leaching occurred at a long term average annual rate of 8-9kg N/ha/yr. The direct cost of this fertiliser loss is low. The indirect consequence of nitrate leaching on soil acidification and potential water contamination would add to this cost. These costs are not quantifiable at present.

The major sustainability issues relate to soil acidification, which occurred both in the topsoil and subsoil, and water imbalance. Water balance modelling showed that deep drainage could only be decreased to a significant extent by changes in land use. Spatial analysis of deep drainage and of financial margins showed that some of the poorest financially performing areas of the farm are also the most leaky. This offers opportunity for land use change, with potentially favourable financial impacts for the grower.

Tools for calculating deep drainage, nitrate concentration in drainage water, N fixation, nutrient balance and financial margins can be incorporated as monitoring tools in environmental management system (EMS) and applied elsewhere in the Mediterranean regions of Australia.

Recommendations

The tools developed for determining nutrient balance, nitrate concentration in drainage water and deep drainage and for financial analysis are valuable for economically and environmentally sound farm management. These tools should be incorporated into an EMS to allow performance to be mapped and managed.

The issue of K depletion reported here is being addressed in a separate project (CSO205) and current rapid adoption of K use in WA is expected to overcome the problem. The agronomic importance of Mg depletion is not known and should be investigated.

Matching paired bushland and cultivated sites showed adverse trends in soil properties. Some, such as those associated with nutrient depletion, can be reversed rapidly. Trends in subsoil acidification are more difficult to reverse and management options should be developed for grower adoption as part of the new GRDC initiative into managing hostile subsoils.

The biggest sustainability issue is water imbalance leading to salinity, nutrient leaching and soil acidity risks. The approach of mapping yield, and hence profits, simultaneously with deep drainage for different land use scenarios offers a powerful tool for land management.

The scientifically published method for calculating deep drainage spatially is based on soil type polygons. The accuracy of mapping those polygons can be increased by spatial modelling using continuous data sets, such as Digital Terrain Models, Electro Magnetics and Gamma Ray Spectrometry.

Achievements/Benefits

This project publicised the adverse impact of K depletion. This has resulted in a recent rapid increase in K fertiliser use, gradual reversal of the K imbalance and increased profits. The implication of Mg depletion in the wheatbelt is unknown and needs to be investigated, together with the implication of imbalance uncovered for N.

Spatial modelling of yield maps was used to determine the spatial patterns of nutrient removal in grains. In wheat, the lowest nutrient accumulation and removal in grains consistently occurred on white sandy soil types because of low yields. The low yield resulted in a corresponding low dollar margin for this soil type. Water balance modelling using the Agricultural Production Systems simulator (APSIM) showed that these sandy soil types were also the most leaky. For wheat, these are the poorest performing soil types both financially and environmentally. The APSIM model was further applied at a regional scale and scenario modelling showed that up to about a half of the regional area composed of the sandier soil type should be planted to perennial vegetation in order to decrease deep drainage by a third. The inclusion of lupins in the farming system, however, changed the spatial pattern of crop profitability, as this crop consistently performed better on the sandier soil types. This reversal of match between crop performance and soil type complicates the delineation of management zones for land use.

This project's findings were disseminated at industry meetings and published for the wider scientific community. The tool for measuring spatially variable nutrient balance and profits can be implemented as a monitoring tool in EMS.

Other research

Development of monitoring tools for EMS based on ISO14001 to take account of spatially variable efficiency of nutrient and water use should be given high priority.

Yield maps are currently accurate. In order to match this accuracy, there is a need for tools for more direct measurement of spatially variable pasture production than current estimates from available water by satellite imagery.

Mg is an important component of chlorophyll and is needed for photosynthesis.There is a need to evaluate the potential implications of Mg depletion on cropgrowth and grain yield.

A priority is scenario analysis of land use options based on climate and longterm sustainability in order to determine impact on drainage, soil properties and profits.

There is a need to investigate the implications of N imbalance on the current negative trend in grain protein content in Australia.

Additional information

A scientific paper was produced that describes the approach to quantifying nutrient balance at paddock and farm scales. The paper deals with fertiliser inputs, atmospheric inputs, removal of nutrients in farm products, N fixation, N mineralisation from soil and organic residues and leaching. The approach was applied to two typical farms identified on the basis of the GRDC-funded Planfarm Benchmarks survey of WA wheatbelt farms and the nutrient balance findings reported.

Tools were developed for quantifying nutrient flows and, hence, the causes of nutrient imbalance, increases in nitrate concentration in drainage water and deep drainage. The work on quantifying nutrient flows and nitrate contamination of drainage water was reported as part of the nutrient balance publication. The deep drainage work is a separate scientific publication that quantifies drainage under current situations and under different land management scenarios. An additional output is measurement of the impact of nutrient imbalance on soil properties at matching paired cultivated and uncultivated sites. This work will be published separately. These tools are available for monitoring environmental performance and have been recommended to Agriculture Fisheries and Forestry Australia (AFFA) and the Mingenew-Irwin group (MIG) as part of a proposed EMS pilot in WA.

Development of pedotransfer functions to estimate leaching loss

Values of both drainage and nitrate concentration in drainage water are needed to calculate leaching loss. The decision support system for agrotechnology transfer (DSSAT) model was used to determine drainage based on the water retention properties of different soil types occurring on-farm and on local rainfall scenarios. This model uses a 'tipping bucket' approach similar to that used in APSIM for determining drainage. The modelled drainage values for different soil types are shown in Figure 1. Comparison of the modelled values with seven sets of data reported in the literature showed that the modelled estimates were reasonably accurate (Figure 2).

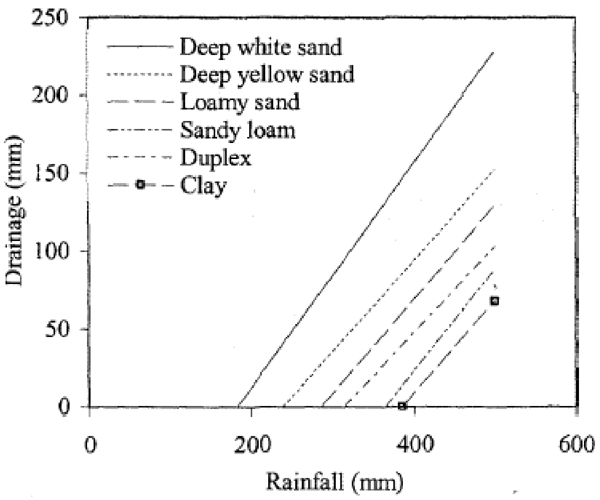

Figure 1. Model estimate of annual drainage for different soil types and rainfall scenarios in Western Australia.

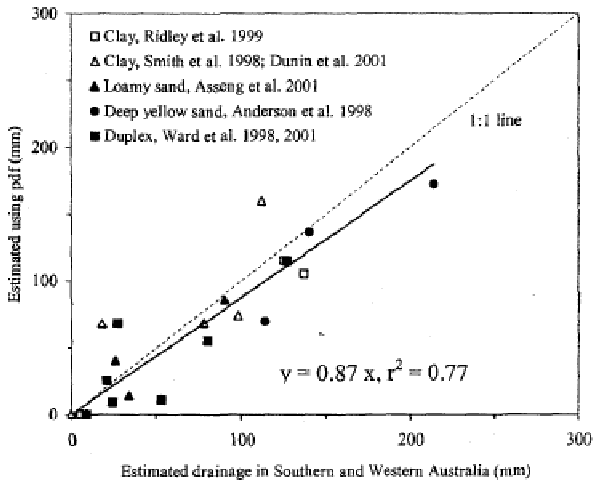

Figure 2: Comparison of estimated drainage using DSSAT model for different soil types with values reported in Southern and Western Australia.

The nitrate concentration in drainage water was estimated from the amount of mineral N available in the soil (Figure 3). This gives an estimate of the severity of water contamination and a way to calculate nitrate loss by leaching.

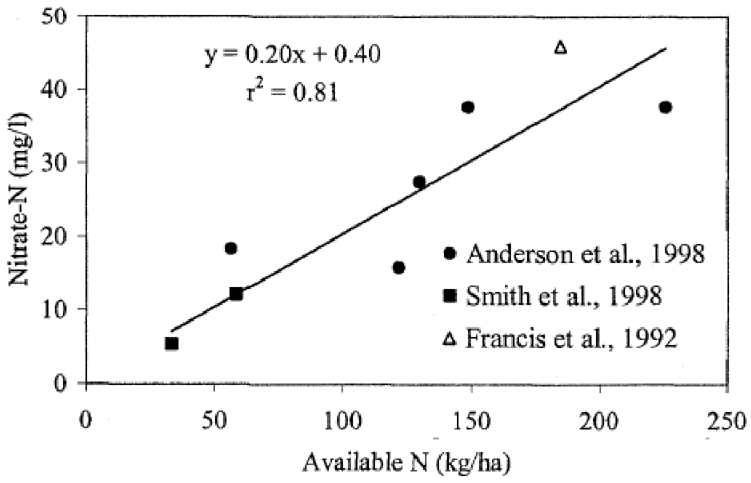

Figure 3. Relationship between nitrate-N concentration in drainage water and total available N in the soil.

Long-term farm-scale nutrient balance

Mediterranean

Using a mass balance model, inputs and removal of N, P, K, S, calcium (Ca) and Mg were calculated on a mixed farm with about half of the farm land devoted to pasture (Farm 1) and on an intensive cropping farm with only 10% of the land devoted to pasture (Farm 2). Fertiliser inputs, N fixation by legume crops and pasture, nutrient removal in harvested products (grain, wool and meat) and leaching loss were considered. Data for fertiliser use and crop yield for the period from 1962 to 1998 were gathered from growers' records. N-fixation and leaching loss were estimated using modelling and pedotransfer functions developed from data reported in the literature and by modelling. A summary balance for the two farms is shown below (Table 1).

Table 1: Area-weighted averaged N, P, K, S, Ca and Mg flows and balance (kg/ha per year) over 38 years from 1962 to 1998 at farm level.

N					P	K	S	Ca	Mg	
Inputs	Fixed	Removed	Leached	Balance	Balance					
Farm1	8.1	31.5	22.1	8.3	9.3	6.7	-3.1	8.9	14.8	-1.3
Farm2	12.0	28.1	33.9	8.8	-2.7	4.1	-5.1	3.9	22.6	-1.8

The inputs of P and S exceed removal of harvested products by a factor of two to five. Soil P measurements showed that available soil P (Colwell P) was typically above 20mg/kg in most paddocks on the two farms. Corresponding Colwell P on similar soils in bushland in the region was less than 5mg/kg. Although P is relatively immobile, its accumulation may result in increased risk of P transfer to surface and groundwater bodies.

The K balance for the two farms for the period 1962 to 1998 was negative because of insufficient K fertiliser inputs, compared with exports of K in harvested products. The progressive depletion of soil K reserves led to deficiency, which is a limiting factor to crop production on many light textured soils and duplex soils.

N balance was slightly negative for the farm with a more intensive cropping history. Such an imbalance may be linked to the negative trend in grain protein content reported in Australia. The N balances for different crop rotations suggest that N-fixation in clover-based pastures plays a very important role in supplying N to the farming system. The estimated N fixed by clover-based pasture ranged from 20 to 87kg N/ha per year over the period, with a mean of 44kg N/ha per year, which is equivalent to the fertiliser N inputs to wheat in the 1990s. This estimate is within the range of N fixation reported for clover based pasture in western and eastern Australia.

N leaching accounted for 18-21% of total inputs of N from fertilisers and N-fixation. The estimated N leaching loss is comparable with other studies in a similar environment. The actual amounts of leaching loss depend on soil types, rainfall and total available N content in the season. The leaching losses were much greater in deep sands than those in heavy texture soils because of their low water holding capacity (WHC).

It was concluded that the traditional wheat-pasture rotation system with adequate N inputs in the wheat phase appears to be sustainable in terms of N balance and that crop intensification may result in N deficiency at current rates of N fertiliser use. Accumulation of P in the cropping systems in the wheatbelt may result in increased risk of P transfer to surface and groundwater bodies. Under current cropping management, soil K and Mg reserves are at risk of depletion. Low soil K is becoming a limiting factor to crop production and fertiliser K addition is necessary, especially on sandy soils. The yield implication of Mg depletion from the limited soil stock in the wheatbelt is still unknown.

Current nutrient flows

Yield maps available for the more intensive cropping system (Farm 2) allowed determination of the spatial pattern of nutrient removal in crops since 2000 and an examination of these patterns in relation to soil types, irrespective of paddock boundaries. An example of N removal by wheat (blue) and lupins (green) harvests in 2000 is shown below (Figure 4).

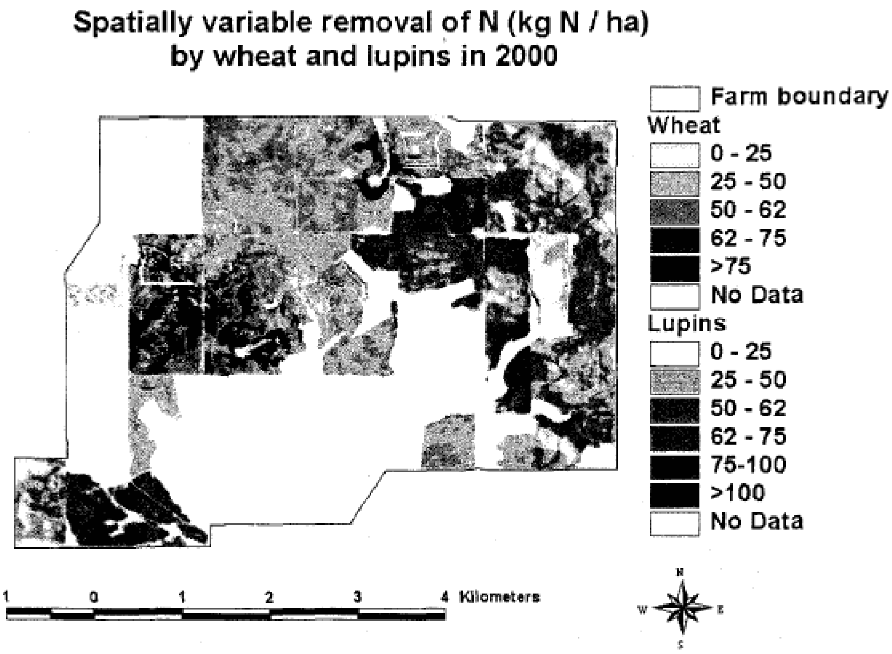

Figure 4: Nitrogen removal in wheat based on yield maps and nitrogen content.Only a small area (65ha) of white sand (marked 3 on map) was planted to wheat in 2000. Total N recovered in grain from this area was 42kg N/ha, compared with 51kg N/ha recovered from the remaining soil types.

Changes in soil chemical properties during cropping

The effect of cropping on soil properties was measured on matching paired cropped and bushland sites by chemical analysis of the soil profile. Nutrient imbalances resulted in lower K and Mg contents in the soil profile and increased P content (Figure 5). Acidification occurred during cropping and in one case (Department of Agriculture WA site), this was treated by liming. The effect of lime applied at the AgWA site in 1999 was restricted to the topsoil.

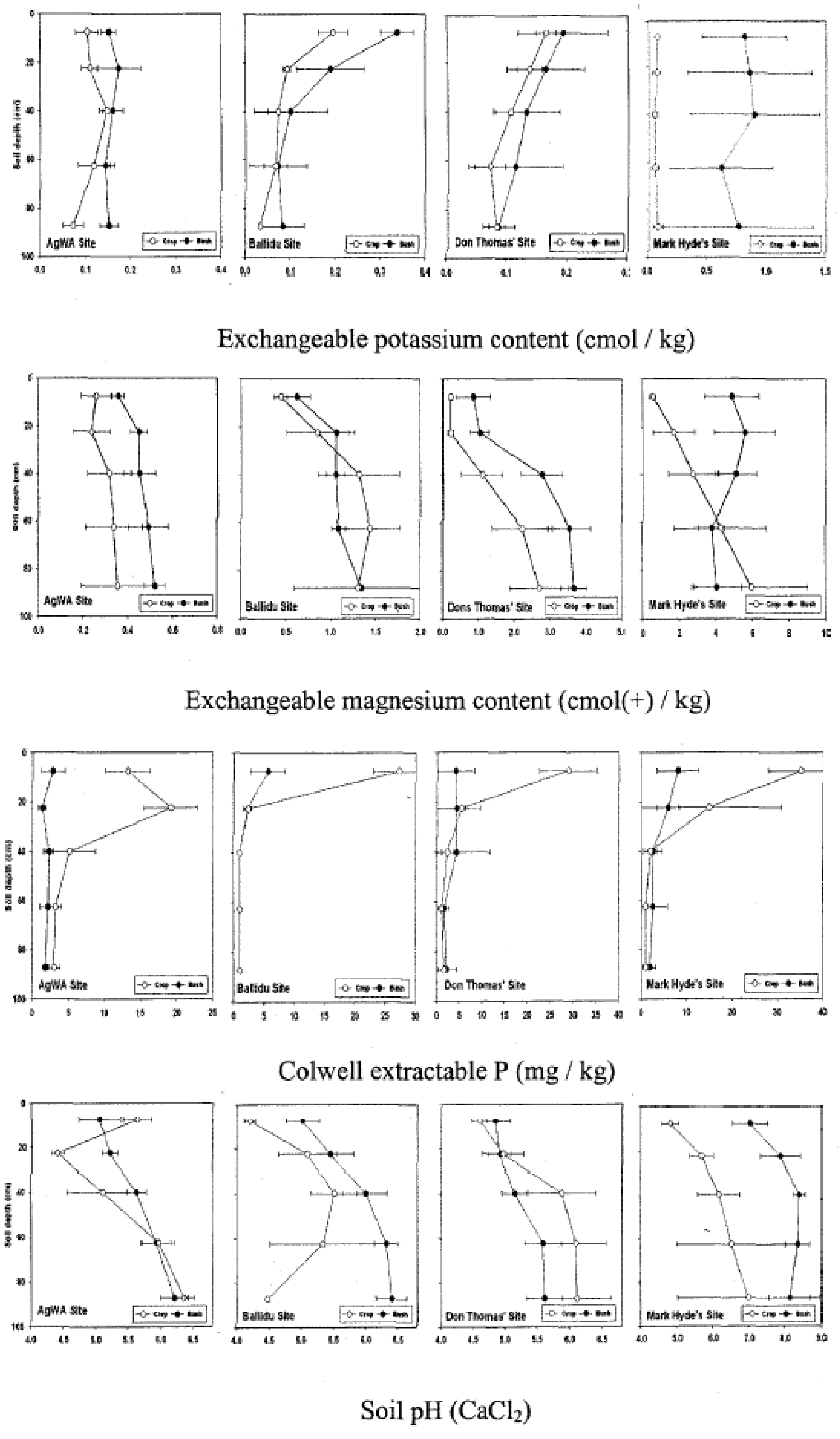

Figure 5. Comparison of soil properties by depths (y-axis in cm) under matched cropping (open circles) and bushland sites (solid circles).

The Economics of nutrient balance

Table 2 represents the ratio of fertiliser input to cropping income for each of the five soil types for Farm 2 for the period 1998 to 2001. A higher ratio represents lower income relative to fertiliser use. The white sandy soil type generally had a higher ratio, except for in 2000, when this soil type was mostly sown to lupins. The lower ratio was due to the lower application of fertiliser to the lupin rotation. This apparent efficiency on the white sand soil type was offset by a lower income return from lupins in 2000 (Table 4).

Table 2. Ratio of Fertiliser Cost to Cropping Income by soil type, 1998-2001.

Year	Loamy Sand	Gravel Loamy Sand	White Sand	Yellow Sand	Duplex Sand
1998	0.14	0.13	0.17	0.13	0.17
1999	0.12	0.11	0.17	0.09	0.13
2000	0.11	0.14	0.17	0.15	0.12
2001	0.14	0.16	0.18	0.16	0.16

The leaching of nitrogen 1999-2001
Table 3 shows the amount of N leached and the direct cost to the grower for 1999 to 2001. The white sand had one of the highest leaching rates due to high drainage values. The heaviest loss occurred in the wettest year of 1999 (599mm). Leaching was lower in the drier years of 2000 and 2001. The direct cost of N losses was small. Additional costs may occur as a result of water contamination and leaching-induced soil acidification.

Table 3. Nitrogen leaching for the years 1999-2001.

1999		2000		2001		Total Kg N/ha	
Soil Type	Kg N/ha	$/ha	Kg N/ha	$/ha	Kg N/ha	$/ha	1999-2001
Loamy sand	20.0	7.4	0.0	0.0	0.0	0.0	20.0
Duplex	14.9	5.5	1.9	0.5	2.8	1.1	19.6
White Sand	19.6	7.3	7.3	1.9	17.0	6.7	43.8
Yellow Sand	18.2	6.8	8.9	2.3	9.5	3.8	36.6
Gravely loamy Sand	25.5	9.5	5.7	1.5	7.2	2.8	38.5

Yield variability resulted in differences in dollar margin obtained with different soil types (Table 4). The white sand, which occupies approx. 17 % of production areas, gave the lowest margin but also had the largest values of deep drainage and leaching loss. It is the poorest performing soil.

Table 4. Dollar margins classified by different soil types (S/ha).

Soil Type	1998	1999	2000	2001	Mean
Loamy Sand	184	149	103	403	182
Gravely Loamy Sand	249	122	148	289	192
White Sand	149	81	33	255	124
Yellow Sand	213	168	94	251	174

Duplex Soil	188	155	82	301	168

Papers

M.T.F. Wong, K. Wittwer and H. Zhang (2000). Historical nutrient balance at paddock and whole farm scales for typical wheatbelt farms in the Dowerin - Wongan Hills area. Crop Update 2000.

G. Pracilio, S. Asseng, S.E. Cook, G. Hodgson, M.T.F. Wong, M.L. Adams and T.J. Hatton (2003). Estimating spatially variable deep drainage across a central eastern wheatbelt catchment. Australian Journal of Agricultural Research, 54, 789-902.