FINAL REPORT

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

IPN00003

Nutrient Performance Indicators

PROJECT DETAILS

PROJECT CODE:	IPN00003
PROJECT TITLE:	NUTRIENT PERFORMANCE INDICATORS
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Summary

The efficiency of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) use in the grains industry, as well as all agricultural production, using consistent and transparent methods was estimated. Regional and national balances show annual, spatial and industry variation. When considered across all sectors, P removal is significantly less than P supplied, while K and S application are significantly less than the amount of K and S removed in products. Nitrogen supplied, including fixed N, is generally less than N removed. Data collected from 500 farm paddocks over four or five years were similar and it is proposed that existing tools be used through farming systems groups to build a reference set for growers to benchmark nutrient efficiency.

product registrations listed in PUBCRIS for current information relating to product registration.

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

The information contained in these older reports is now several years old, and may have been wholly or partially superseded or built upon in subsequent work funded by GRDC or others. Readers should be aware that more recent research may be more useful for their needs. Findings related to agricultural chemical use are also potentially out of date and are not to be taken as a recommendation for their use.

Conclusions

The N-partial nutrient balance (PNB), P-PNB and K-PNB were estimated as 1.02, 0.44 and 1.8, respectively, for grain production in Australia. The N-partial factor productivity (PFP), P-PFP and K-PFP values were 52kg grain/kg N, 128kg grain/kg N and 724kg grain/kg K. The N-nutrient balance intensity (NBI), P-NBI and K-NBI values were +4.6kg N/ha, +7.2kg P/ha and -5.7kg K/ha. Compared to other countries, Australia generally has modest N imbalances using the assumptions implicit in the current literature. The P balances are generally positive (removal<use).

In comparison to other countries, the partial balances for P for Australia are relatively low, with more P supplied in fertiliser than is removed in products in Australia. The K balances indicate that more K is removed than is supplied which is similar to the global mean, while the N imbalance is modest by global standards.
Similar to the whole of Australian agriculture, the grains industry shows a negative N and K balance and a positive P balance. These values are consistent with the data reported earlier from the international survey by Norton et al. (2014) and the Australian Agricultural Assessment (2001).

The data from the 500 fields reported showed N-PNB was generally higher than 1.0, while P-PNB is generally lower than 1.0. The N-PNB is higher than 1.0 for over half the fields assessed in all regions except the Mallee where 39% were above1.0. The P-PNB value reported in this study is lower than data from other countries and this is likely a consequence of the P-sorbing soils fixing some of the applied P.

The P-PFP values collected from the farms surveyed are generally approx. 200kg grain/kg P. The N-PFP values show wide variations due to rotation and soil N status and around half the values from the growers' fields are less than 50kg grain/kg N suggesting that those low values may be limited by some biotic or abiotic constraints other than nutrients. It is debatable if the high values indicate that N supply is limiting production, but rather that extra N is being drawn from soil reserves, either from new or old organic N sources.

Despite the limitations of PNB, PFP and NBI, if growers can develop these nutrient performance indicators for their fields or farms, it will allow them to index the performance against others. The PNB will advise whether nutrients are being added or removed from the field, the NBI indicates the magnitude of that change and the PFP indicates the sort of return achieved for the nutrients supplied. These metrics are indicators and are not efficiency measures or environmental loss assessments and so should be the start of the process of investigating opportunities for improving nutrient performance. They need to be aligned with other indicators such as soil nutrient levels or other soil health measurements.

Recommendations

If growers are to be encouraged to investigate performance indicators, reference methods reported should all follow the same protocols, preferably through a web-based calculator. There are important aspects of developing the methods to estimate indicators. These include validation of the biological nitrogen fixation (BNF) calculations, particularly for green and brown manure crops or pastures, verification of the nutrient concentrations in products removed, including crop residues, nutrient inputs from manures considered where appropriate, and nutrient losses from residue removal or burning are considered.

On-line calculators could be based on an on-line nutrient balance calculator (http://brasil.ipni.net/article/BRS-3293) developed by the International Plant Nutrition Institute (IPNI) Brazil that is being adapted to other regions. Alternatively, GRDC may consider adapting the Lime and Nutrient Balance calculator to a web-based platform. Irrespective of the tool selected, it should use regional grain nutrient concentrations and validated BNF estimates to derive PNB, NBI or PFP to be reported back to growers.

Defining the success of a nutrient management research project solely on the basis of the efficiency measured due to intervention is not likely to lead to positive outcomes overall. Certainly getting improved comparative efficiency, such as among different nutrient sources, or with different timings or through alternative placement strategies, are all valid ways to make comparisons, particularly when done at the same rate. There is no absolute number that can be used to define an acceptable efficiency, as the different loss processes have different impacts. For example, where a recovery efficiency (RE) or PNB are less than one, the nutrient that is unaccounted for may be entering lower available nutrient pools and/or contributing to increased soil test levels. Alternatively, where soil nutrient status is high, a high RE or PNB (i.e. higher than 1) may be desirable to target, while if nutrient status is low, a high PNB would be mining the soil resource.

Metrics, like PNB and agronomic efficiency (AE), do not provide any intelligence about the fate of the nutrients not taken up and removed by the crop. These metrics are not environmental indicators and a low or high PNB or AE is not necessarily good or bad. Losses may or may not be detrimental environmentally, and residual nutrient values may be significant. The recovery and productivity of nutrient inputs are better suited to long term studies of three to five years rather than single year responses.

If there is a desire to maintain an ongoing review of the performance of nutrients for the Australian grains industry, good quality production data are available at national, state and natural resources management (NRM) level through the Australian Bureau of Statistics (ABS) data collection services. Nutrient concentrations for Australian produce are known although this requires on-going verification and monitoring, particularly of regional values. In combination, the removal of nutrients can be reasonably estimated at a national and a state level but the precision is diminished when downscaled to regional (e.g. NRM) level. GRDC may consider working more closely with Fertilizer Australia, ABS and the Australian Bureau of Agricultural and Resource Economics (ABARE) to develop reliable good quality farm scale data. Additional paddock surveys present an excellent opportunity to capture some of these data, but the grains industry does not exist in isolation from other agricultural industries and nutrient inputs for pastures used for grazing livestock are likely to have residual value into grain production activities.

Outcomes

Nutrients represent a major investment for grain growers and monitoring their efficient and effective use represents an important aspect of long and short term management. In addition, inefficient use of nutrients can represent both an economic and environmental loss. There is international interest in monitoring nutrient performance through a range of metrics, including PNB (removal to use ratio), PFP and NBI. No individual metric provides a complete assessment of nutrient performance, and linkages to soil health and economic returns are also required.

This research established a series of protocols for collecting data to derive nutrient performance indicators that growers can use to reflect on the efficiency and effectiveness of their nutrient management strategies.

Achievements/Benefits

Because of the importance of fertiliser use economically and environmentally, there is increasing interest in developing ways to evaluate the efficiency and effectiveness of their use on farms. While there are many metrics that can be used as nutrient performance indicators (NPI), three in particular have become widely quoted. They are PNB, the quotient of nutrient removed in product and nutrient supplied to the crop, PFP, the quotient of grain and nutrient supplied to the crop and NBI, which is the amount of nutrient in deficit or surplus per hectare.

The nutrient performance indicators PNB, PFP and NBI are useful in assessing system performance. They are not indicators of environmental fate. These metrics can be applied at a range of scales from fields, to farms, to regions, to countries. It is critical to ensure that the data being used are transparent, auditable, referenced, consider all nutrient sources, are regionally relevant and appropriate to the intention as to how the metrics are to be interpreted. When taken alone, the numerical value of these indicators is of limited value, and they need to be considered over time and in concert with other measures. They are not

environmental or economic indicators in their own right and interpreting them as such is inappropriate. The indicator values calculated need to be linked to other indicators such as yield and soil test values to gain an appreciation of their significance.

Norton et al. (2014) estimated the N-PNB, P-PNB and K-PNB as 1.02, 0.44 and 1.8, respectively, for grain production in Australia. The N-PFP, P-PFP and K-PFP values were 52kg grain/kg N, 128kg grain/kg N and 724kg grain/kg K. The N-NBI, P-NBI and K-NBI values were +4.6kg N/ha, +7.2kgP/ha and -5.7kg K/ha. Overall, Australia has modest N imbalances using the assumptions implicit in the current literature, compared to other countries. P balances are generally positive (removal<use).

In comparison to other countries, the P-PNB for P for Australia are relatively small (approx. 0.5) with more P supplied in fertiliser than is removed in products in Australia. The K balances indicate that more K is removed than is supplied which is similar to the global mean, while the N imbalance is modest by global standards. The national accounts for nutrients require very good quality data presented in a consistent format with clear assumptions presented if they are to be reported to groups such as the United Nations Environment Programme (UNEP) or Organisation for Economic Cooperation and Development (OECD).

Using currently available data on production and nutrient use, nutrient performance indicators can be estimated at a national level, although these data (and many other estimates) either ignore or over simplify the input of biological N fixation. High quality production data are available down to the NRM zone (as defined by the ABS), but there are few sources of good quality fertiliser use by crop data at a regional scale. Different data sources on regional fertiliser use by crops were compared, and while there is some concordance, each source has its own problems. The ABS data are not disaggregated by crop and the International Fertilizer Industry Association (IFA) data are only presented by region. The ABS does have some inconsistencies over time in the wording of particular questions concerning land management practices. The quality of the data used and a definition of the industry cohort assessed are important in developing reliable and consistent estimates of these nutrient performance indicators. GRDC is encouraged to consider on-going assessments of field surveys such as the paddock survey.

The assessments undertaken show reasonable consistency in the size and distribution of partial nutrient balances for Australia. In general, Australian agriculture has a near neutral or slightly positive N balance, a positive P balance and a negative K balance. As a consequence, soil P levels are likely to be increasing, while soil N and K levels are being depleted. These values show large inter-annual variation, with nutrient removals (i.e. production) showing larger variation than nutrient inputs. Regional nutrient budgets were developed and are posted for three audit periods on the Centre for eResearch and Digital Innovation at Federation University. This platform could be further developed.

Similar to the whole of Australian agriculture, the Australian grains industry shows a negative N and K balance and a positive P balance, and these values are consistent with the data reported earlier from the international survey by Norton et al. (2014) and the Australian Agricultural Assessment (2001).

Field records of fertiliser use and crop type and yield were collected from 514 fields from 125 growers covering more than 35,000ha over four or five years in south-eastern Australia. The frequency distribution of PNB and PFP derived from these data were skewed to the right, with the mean larger than the median, so that comparing mean regional values is not statistically valid. Because of this, data may be best presented as distributions. The data from the 500 fields reported showed N-PNB was generally higher than 1.0, while P-PNB is generally lower than 1.0. The N-PNB is higher than 1.0 for over half the fields assessed in all regions except the Mallee where 39% were above 1.0. The P-PNB value reported in this study is lower than data from other countries and this is likely a consequence of the P-sorbing soils fixing some of the applied P.

Nutrient performance indicators AE and RE are marginal production or nutrient recovery and these along with PNB and PFP for wheat crops were calculated for N, P and K using N data from 47 Incitec Pivot Ltd field experiments between 2001 and 2011, and the 1,224 P and 172 K experiments drawn from the Better Fertiliser Decisions for Crops (BFDC) database.

Sixty seven percent of N-PNB measures were higher than one, meaning for the year of the experiment, soil N is being mined. This is the same proportion as was estimated from the field survey. The P experimental data estimated that P-PNB was higher than one in 14% of examples, while the field survey estimated that 19% were higher than one.

In general, the rate of nutrient input and the corresponding nutrient performance indicators were inversely proportional and the response of AE, RE, PNB and PFP are shown in Attachment 1. The pattern of an inverse proportion was more obvious for PFP and PNB than for AE and RE and this is largely because the numerator in the latter pair is a marginal value rather than an absolute value.

A meta-analysis of the N dataset was undertaken to compare the information conveyed by the different indicators. The marginal indicators AE and RE are more responsive and therefore informative about the effects of different interventions compared to PFP and PNB. AE and RE are effective as research tools in assessing a range of options to refine management, but in reality they are not suited to field scale assessments. PNB and PFP both reflect changes in application rates, with lower responses at higher rates.

If growers are to be encouraged to investigate the performance indicators, the reference methods reported should all follow the same protocols. This will ensure the nutrient performance indicators are comparable. Important aspects of developing the methods to estimate indicators which include valid BNF estimates, verified product nutrient concentrations, nutrient inputs from manures and nutrient losses from stubble management options.

IPNI Brazil developed an on-line nutrient balance calculator (http://brasil.ipni.net/article/BRS-3293) that is at present being adapted to other regions. This tool will be able to be used with regional grain nutrient concentrations and adopting BNF estimates using the recognised methods. The data will be reported back to growers as PNB, NBI or PFP and there will be the option for single year or multi-year entries. The reporting will be with the number, but the graphic interface will seek to place fields in the cohort that is most appropriate to them, such as region or crop type. With the permission of those entering data, a database will be built from these entries that will then enrich the entire data set. Using the GRDC Lime and Nutrient balance is another option.

Any proposal to further develop these indicators as tools for growers to assess nutrient performance requires a way to communicate the information and an explanation of what the information means. The concept could be to present PNB and PFP values in the distribution graphs (Figure S1, Attachment 1) with the position the grower's data occupies highlighted. Discussions on values are needed, including the effect of different rotations and soil characteristics (e.g. phosphorus buffering index) on interpreting the meaning of the metric.

Research is in a good position to measure the various nutrient performance indicators as the field work invariably contains nil or check plots. Measuring and understanding efficiency improvements are important, but it is highly rate, site and season dependent as shown by the analysis of the data from the BFDC database. A very good AE and RE can be gained if the site selected has a very low nutrient status, and a low rate of fertiliser is supplied to crops growing under good conditions. However, the vagaries of field research make site selection, even with comprehensive soil testing, difficult. It should also be clear that the highest nutrient efficiency is not related to profitability, and indeed the highest efficiency is often at the start of the response curve rather than the point at which marginal returns meet marginal costs.

Good quality data on nutrient supply from fertilisers to all agricultural industries is available from Fertiliser Australia down to a state level. Scaling of the Farm Survey data does not reflect the industry data, so processes to monitor nutrient use patterns for the grains industry need to be addressed. The 'Paddock Survey' presents an excellent opportunity to capture some of these data, but the grains industry does not exist in isolation from other agricultural industries and nutrient input for pastures used for grazing livestock are likely to have residual value into the grain production activities - and vice versa.
When considering nutrient monitoring for the grains industry, the purpose will determine the scale and timeframe, and the processes adopted need to be clearly articulated and systematically and consistently applied.

Other research

Development of an on-line nutrient balance calculator for growers to estimate PNB, PFP and NBI at a field level.

Develop and publish regional nutrient concentrations of grain and crop residues.

Intellectual property summary

Current data derived from grower surveys is not individually identified to protect the confidentiality of the information provided by individual growers. There have been no commercialisation activities, but IPNI is proceeding to adapt the Brazilian calculator to a broader geography. The protection and sharing of any IPNI intellectual property (IP) can be discussed as that project proceeds.

Additional information

A paper has been submitted to the International Nitrogen Conference for December 2016 (see Attachment 2).

Attachments

1. Nutrient performance indicators scoping study.

2. Conference paper.