Managing the production potential of the soils of the Southern and Central Tablelands – key messages from the LANDSCAN™ program

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Abstract: *In almost every plant production system there are constraints holding back maximum potential. Recognising the constraints, identifying the one which is most limiting and forming a plan to address it across a variable landscape is a significant challenge for Tableland producers. Constraints can be broken down to those which cannot be changed, therefore affecting the choice of appropriate enterprise; and those which can be changed, giving us a framework to guide investment. The common constraints that affect landuse are soil depth and topography, while deficiencies of the nutrients phosphorus and sulphur are common constraints that limit production. A large number of soil test results (3957) was collected during the delivery of the LANDSCAN™ program. The trends in this database provide powerful insight into the most common nutrient constraints affecting production in the Southern and Central Tablelands. The test results can be assigned to agro-ecological regions and so trends can also be observed across regions and enterprises. These trends should not be used as the basis of decision making as there is considerable variation at the farm and paddock level. Producers need to test rather than simply guess their soil constraints. However, at an industry level, the database can provide valuable information, which may be used to direct research, development and extension efforts.*

Key words: variable landscape, capability, target levels, limitation

Introduction

LANDSCAN™ is a course designed and delivered by NSW Department of Primary Industries (NSW DPI) for farmers who wanted to understand how they might allocate resources to differing areas of their variable landscape. LANDSCAN™ courses were first held in 2003 and since then more than 500 farm businesses have participated.

An integral part of the LANDSCAN™ course is the soil sample test results from participants' own farms. Participants were encouraged to take a range of samples that represent the various soils and landuses on their property. Most sampled at least one paddock, but some chose to sample as many as ten paddocks. Over time, this has built a considerable database of soil test results. As the soil testing process and laboratory methods used were the same for other NSW DPI soil testing and monitoring courses, such as those funded by the dairy industry, the results from these have also been incorporated into the database.

This paper considers the results obtained between 2009 and 2012, when 3957 soil tests from 2497 paddocks were collected from the Tablelands, Slopes and Coast regions of NSW. There is data available from paddocks tested from 2003–2009, but this is not been included in the results discussed here.

Participants worked through a structured course in a framework that highlighted any constraints that may be affecting achievement of goals for their property.

There were constraints to production that participants considered other than those revealed through soil testing. Often there were indicator plants or other visible symptoms that suggested that of one of these constraints may be affecting production. During each paddock visit in each session attention was given to various constraints, including:

- Soil depth and texture
- Soil moisture
- Slope
- Aspect
- Shelter
- Drainage

- Infrastructure e.g. paddock size)
- Weeds

Methods

Soil sample collection

Soils were sampled by the participants, who were given training in suitable methods of sampling, including number of samples per paddock and which areas or situations to avoid. Participants were asked to sample paddocks in which they wanted to make a resource allocation decision and which also represented the diversity of paddocks across their property. They were given training to ensure that the area sampled was representative of much larger areas on their property. The location of each paddock was recorded using GPS so they could be located for follow-up testing and monitoring by the participants. All participants of LANDSCAN™ courses were required to take samples between 0–10 cm (topsoil) and 10–20 cm (subsoil). However, some of the test results in the database came from programs where the subsoil sample was not required.

Table 1. Soil test assays performed on topsoil and subsoil samples taken in the LANDSCAN™ program.

Assay	Topsoil	Subsoil
pH (1:5 Water)	✓	✓
pH ($CaCl_2$)	✓	✓
Organic Carbon	✓	
Phosphorus (Colwell)	✓	
Phosphorus Buffer Index	✓	
Available Potassium (Amm-acet.)	✓	✓
Available Potassium (Colwell)	✓	✓
Sulphate Sulphur (KCl40)	✓	
Electrical Conductivity	✓	✓
Cation Exchange Capacity	✓	✓
Aluminium (KCl)	✓	✓
Aluminium Saturation	✓	✓
Calcium (Amm-acet.)	✓	✓
Magnesium (Amm-acet.)	✓	✓
Sodium (Amm-acet.)	✓	✓
Sodium % of Cations	✓	✓
Potassium (Amm-acet.)	✓	✓
Calcium/Magnesium Ratio	✓	✓
Potassium/Magnesium Ratio	✓	✓

Soil testing

Soils were tested by Nutrient Advantage Laboratory Services in Werribee, Victoria. The assays are shown in Table 1. The main purpose of the subsoil tests was to determine any changes with depth for pH and some nutrients. Information about soil physical characteristics was recorded by course participants but not collected by the course deliverer.

Geography

The LANDSCAN™ program was delivered across NSW but principally in the Tablelands and Coast regions. Due to different production environments represented by participants, the soil test results were split into broad agro-ecological regions. The regions and number of paddocks tested in each can be seen in Table 2. Soil tests from properties that supported a dairy enterprise were separated to observe any effects

Table 2. Number of soil samples taken by region during LANDSCAN™ courses.

	Topsoil tests	Subsoil tests
Northern Tablelands	48	48
North Coast	105	Nil
Hunter	326	306
Sydney Basin	105	27
Central Tablelands	99	35
South/West Slopes	389	383
Southern Tablelands	1036	538
Southern Highlands	78	73
South Coast	11	9
Dairy Industry	300	41

of high input systems and landscape advantages. The majority of samples taken from the North Coast and Hunter regions were dairy enterprises.

Results

Discussions during the LANDSCAN™ course focused on the most limiting constraints. When it came to the interpretation of the soil test results, the focus was on phosphorus (P), sulphur (S) and pH ($CaCl_2$).

The P results (Fig. 1) for the North Coast and Hunter regions were relatively high compared with samples from all other regions, with the median level and range lowest for the Northern, Central and Southern Tablelands samples. The P results from the Dairy Industry samples were also higher than most regions, in particular those dominated by extensive grazing, such as the Tablelands. It is worth noting that soils from the South/West Slopes included samples from paddocks with a long cropping history and tended to have P levels above those from paddocks dedicated to extensive grazing enterprises.

The differences in sulphate sulphur levels are much smaller than those for P (Fig. 2) and it is difficult to draw conclusions from the results based on landuse. Unfortunately, sulphate sulphur was not measured in the subsoil tests so the results do not show any 'bulge' that may be present at depth.

Course participants were also very interested in soil test results for pH and exchangeable aluminium. The wide range of results and outliers (Fig. 3) created opportunities to discuss the merits and value of liming.

To provide participants with an indication of the P fertility status of the soils they had tested, the P level from each soil test was plotted against the target Colwell P levels (Table 3). These target levels are the benchmark levels

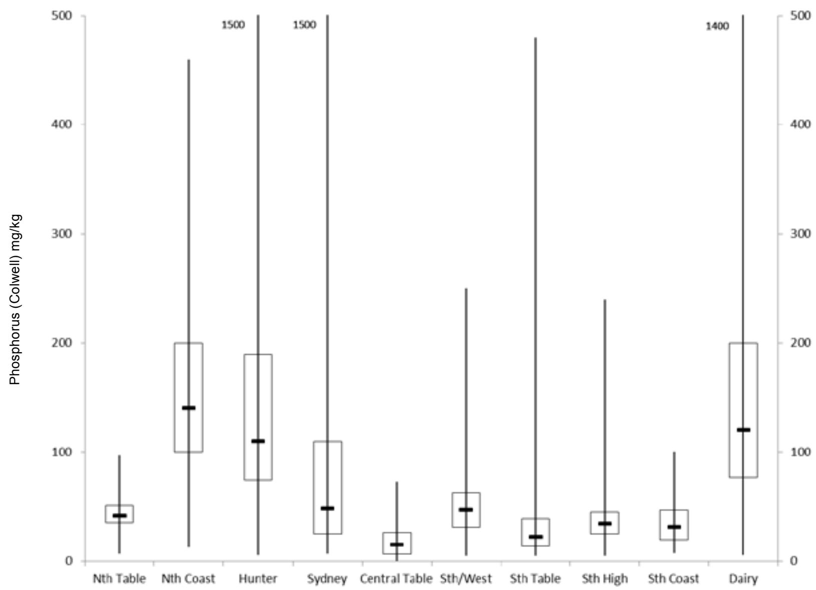

Figure 1. Box plots showing soil phosphorus (Colwell) levels measured in the top soil 0–10 cm. The minimum, lower quartile, median, upper quartile and maximum levels from the database are graphed. The line in the middle of the box represents the median level, the upper and lower edges of the box represent the 75th and 25th percentiles, respectively (i.e. the central 50% of all values are within the box). The upper and lower whiskers represent the 90th and 10th percentiles. Note that Phosphorus Buffer Index was not taken into account in these results.

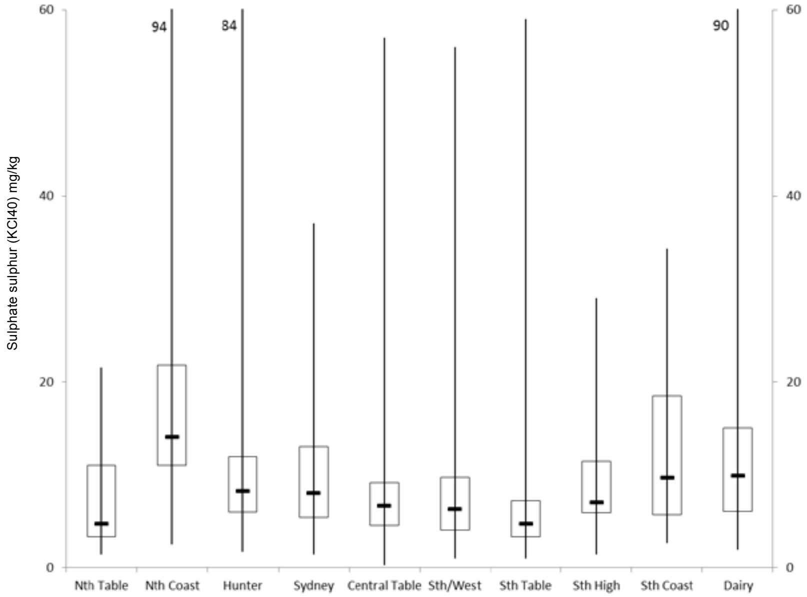

Figure 2. Box plots showing soil sulphate sulphur (KCl40) levels measured in the top soil 0–10 cm. The minimum, lower quartile, median, upper quartile and maximum levels from the database are graphed..

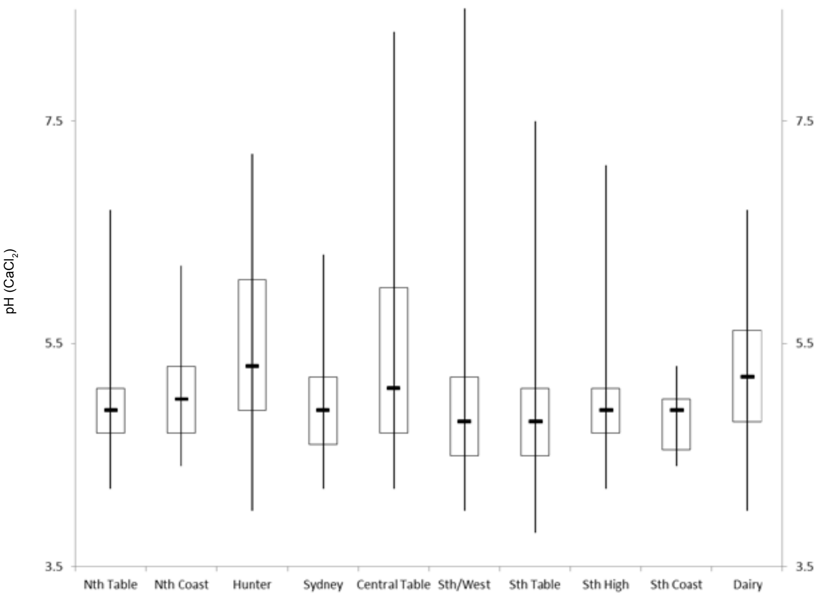

Figure 3. Box plots showing the soil pH ($CaCl_2$) levels measured in the topsoil 0–10 cm. The minimum, lower quartile, median, upper quartile and maximum levels from the database are graphed.

Table 3. Target levels used to plot the phosphorus, sulphur pH and potassium indices in Figure 4.

Nutrient	Target level (mg/kg)
Phosphorus (Colwell)	
PBI range 0–14	23
PBI range 15–35	26
PBI range 36–70	30
PBI range 71–140	34
PBI range 141–280	41
PBI range >281	56
Sulphur	8
Potassium	0.4 meq/100 g

Source: Clements *et al.* (2005)

provided to participants in the LANDSCAN™ Manual (Clements *et al*. 2005) and presented in the Better Fertiliser Decision Project (Gourley *et al.* 2007).

The soil test results for P, S, pH and potassium, from all soil samples taken by participants from Southern Tablelands courses, are presented as a soil constraint index in Figure 4. These were the soil attributes that the course participants most commonly wanted to address. The indices were calculated by dividing the soil test value by the target level. An index of less than 1 indicates that the nutrient or pH level is below target, while an index greater than 1 indicates the level is above target. Samples from the Southern Tableland were used for the analysis as this was the largest dataset (1036 topsoil samples).

Discussion

The key objective of the LANDSCAN™ program was to build the capacity of participants to 'read' the landscape and match the natural features with an appropriate enterprise(s) and production targets (Clements *et al.* 2005). Participants were encouraged to use the information gathered during the course and consider the range of results from across their properties to make management and investment decisions.

Not all production constraints can be changed. The constraints which cannot be changed become limitations to the landuse. The constraints which can be changed become the options for investment decisions. It is worth noting that improvements in soil nutrient status are among the easiest, quickest and cheapest investments that can be made on farms.

Soil Depth

There are some common constraints across the geographic regions where LANDSCAN™ has been delivered. Although it is subjective, soil depth is consistently a constraint to enterprises in the Tablelands. The depth of soil usually increases from a shallow soil on hilltops and ridges to deeper soils in the lower slopes and flats. On some properties, the shallowest depth may be in excess of 1 m, while on many more it may be 5 cm, or less. This constraint cannot be practically changed and so soil depth becomes a limitation to the type of landuse.

If the soil is so shallow that it cannot support reasonable vegetation it may only be suitable for occasional grazing or even retired from agriculture. The 'deeper' soils on any property are commonly used for the more intensive enterprises. They are often a 'high input: high output' area that will drive the main enterprise.

Topography

Topography was one of the most common constraining factors in the Southern Tablelands region. Associated factors such as excessive slope, aspect, rockiness and waterlogging are all impractical to change and so must define the type of landuse (Hackney *et al*. 2012). Areas with excessive slope are common and become a significant constraint and a limitation to landuse. The aspect of a site will also affect the production potential (Hackney *et al*. 2010).

Feedback from producers attending the courses indicated that they had developed an appreciation of the value of retaining native pastures in areas of excessive slope or unfavourable aspects. The landuse on areas constrained by topography was often extensive, low intensity grazing.

Nutrients

The soil test results indicate that P and S are the nutrients which consistently constrain pasture production in the Southern Tablelands (Fig. 4).

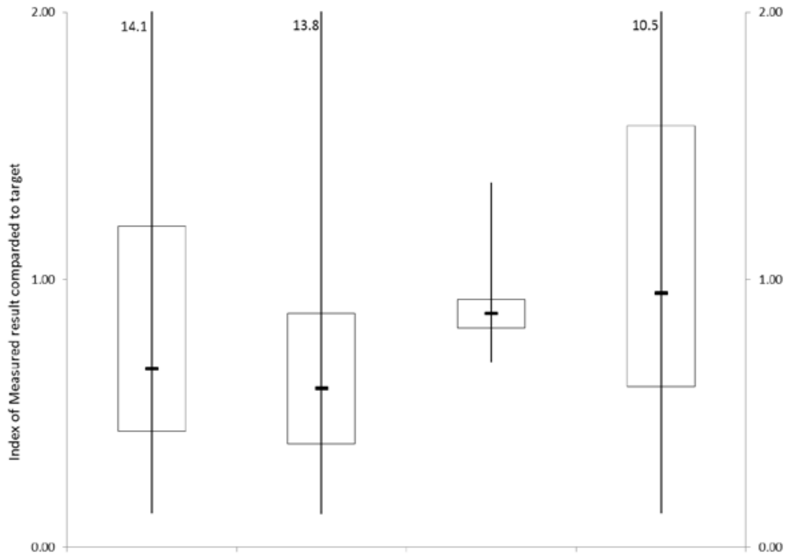

Figure 4. Box plots showing the soil constraint index using measured results against target levels for phosphorus, sulphur, pH and potassium in the topsoil 0–10cm in the NSW Southern Tablelands. A result of 1 means the measured result is the same as the target, <1 is below target (e.g. 0.5 is half of the target) and >1 is in excess of target (e.g. 2 is twice the target). The minimum, lower quartile, median, upper quartile and maximum levels from the database are graphed.

The difference in nutrient levels between regions shown in Figures 1, 2 and 3 can be attributed to a combination of soil type, inherent soil fertility and landuse history. For example, in the North Coast and Hunter regions, areas of deep soils with high fertility and few production constraints, such as the alluvial flats, traditionally attracted intensive industries, such as dairying and horticulture. It is not surprising that such high input, intensive industries are found in parts of the landscape with deeper soils, and fewer production constraints. Similarly, the highly variable landscape, shallow soils and limited arable areas of the North, Central and Southern Tablelands strongly influence landuse. Low input, extensive grazing industries, predominantly supported by native-based pastures, were represented by the majority of paddocks tested by participants from the Tableland regions.

The soil test database developed through the LANDSCAN™ program, combined with local knowledge of the geographical constraints to production, is a valuable resource. For example, examination of results from the Southern Tablelands (Fig. 4) indicate that P and S are the most common nutrient deficiencies identified in the test results, which has been the case for the last five decades. This highlights potential for targeted investment in fertiliser. Course participants armed with this information now have the resources to monitor and manage trends on farm. Regular soil testing can play an important role in fine-tuning and targeting P levels to match production targets. S tends to be a little more difficult to manage due to its mobility but must also be addressed.

Management

The variability of soil acidity is high in each region included in the LANDSCAN™ program. Some of the paddocks tested have a history of liming and are represented by samples with higher pH levels. Soil acidity remains a constraint to pasture production and land development for many areas, particularly in the south of the state and was a major topic covered during the courses.

The Big Picture

The need to address more than one constraint in order to optimise production adds significant complexity to the management of livestock systems. Many sites are constrained by multiple factors. For example, the Tablelands has many sites constrained by slope, low P and S levels, and shallow topsoil. In such situations there is little to be gained by addressing the low P and S levels if the shallow topsoil is the major factor limiting production. At the other end of the spectrum, low pH on a site with deep, alluvial soil and adequate nutrients is a good example of a site where a good economic and agronomic response is highly likely if the limiting factor (soil acidity) were to be addressed. Finding these opportunities within the variable landscape is the key to good investment and the closing message from the LANDSCAN™ program.

The LANDSCAN™ data indicates that the nutrient levels of soils supporting intensive industries tends to be at or above target. In addition there are often fewer constraints. Therefore, the research, development and extension priorities are often likely to be different from the areas more suited to extensive industries, for which the database indicates that nutrient levels are at or below target. This highlights the value of current projects that investigate P management, nutrient efficient pastures and soil fertility benchmarking (Burns *et al.* 2013). The database can also be used to guide extension efforts in agro-ecological regions such as the NSW Tablelands, where there are significant gains to be made in agricultural productivity. Within regions, some businesses will have potential to reduce fertiliser use while others have potential to improve their production through informed fertiliser use.

Conclusions

The range of production constraints on any individual property will vary. The skill of a good land manager is to identify these constraints and then implement a plan to address those that will contribute to their goals while matching the capability of the landscape. If it is not reasonable to address the constraints, an alternative landuse or change of production target may be the best course of action. Often there are multiple constraints at the one site. This may well prevent the area from achieving the level of production needed to warrant investment. Only the producer can make that decision, based on the comparative return on investment across the variable landscape they manage.

The database of soil test results developed during the LANDSCAN™ program, as well as the associated metadata, provides useful information for developing research, development and extension strategies. Combined with historical landuse data and local knowledge the information can be mapped and analysed for trends. This can be used to identify broad constraints which industry may need to address at a regional level. However, at the individual farm level, achieving production targets for enterprises and producers' goals mean that professional agronomic and production advice will always be valued. There is no simple answer which can address all situations in a variable landscape. Producers should continue testing their soils to most accurately determine which constraint is most limiting.

Acknowledgments

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