GOVERNMENT OF
WESTERN AUSTRALIA

Department of
Primary Industries and
Regional Development

iLime Technical Notes

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Version 1, released July 2019

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Introduction

How it works (in brief)

iLime estimates the impact of applications of lime on soil pH, yield and profitability of a paddock or area of soil over twenty years. It does not include other potential benefits of liming such as improved access to nutrients, improved efficiency of use of nutrients by plants, reduced leaching, increased biological activity or reduced non-wetting.

The model uses a dynamic budgeting approach to determine net inputs of acidity or alkalinity in three soil layers (0–10 cm, 10–20 cm and 20–30 cm). The balance of these inputs impacts the change in pH and toxic aluminium in each of the layers and hence the impact on yield of crops and pastures. Two liming scenarios may be evaluated and compared with an unlimed default.

The annual acidification in the model comes from three sources: removal of product, acidifying ammonium-based nitrogen fertilisers and leaching of nitrate. Alkaline inputs come from the lime application selected by the user and its subsequent dissolution (see below). The inputs of alkaline into each soil layer are calculated on a monthly basis. This is adjusted by the annual acidification rate, which is distributed through the profile according to soil texture (the main source of soil acidification in WA is nitrate leaching). The soil pH in each layer is adjusted for the net input of acid or alkaline, taking account of the soil's buffering of pH. Soil pH and toxic aluminium at the end of a year are used to determine the yield potential of the current 'crop' for limed and unlimed scenarios (see 'Yield' below).

How inputs are used

Rainfall Zone

Nitrate leaching is estimated using default values for a grid of rainfall zone and soil texture (see 'Acidification rate' below). The selected rainfall zone also determines the soil water content in each month, which affects dissolution of lime (see 'Lime quality' below).

Soil and initial acidity profile

Three soil layers are considered in iLime, the surface soil (0–10 cm), sub-surface soil (10–20 cm) and deeper sub-surface soil (20–30 cm). Soil texture impacts nitrate leaching, as described above. The gravel %, organic carbon % and exchangeable aluminium class are used to calculate pH buffering capacity.

The Al class relates to the release of toxic aluminium at low pH. Three broad categories are used as there is great variation in levels of toxic aluminium for given soil pH and texture. The 'high' category is representative of soil with low pH and high levels of Al, such as eastern wheatbelt wodjil sub-soil or acidic red sand (e.g. Perenjori). The 'moderate' category includes yellow 'pear tree' sand (e.g. Yuna or Chapman Valley) and loam soil. The 'low' category applies to pale, 'gutless' sand (e.g. Badgingarra and Esperance), soil with high organic matter (>2%) or clay soil.

Crop

The calculated yield in each year, for Scenario A & B and the unlimed, is determined by multiplying the non-acidity limited yield by the yield index for the year in question (see 'Yield' below for detail).

The yield entered for each crop on the Crops page should represent what would realistically be expected, on average, for that crop grown on the soil with its initial pH. iLime does not directly account for seasonal variability, but different levels of production and inputs may be selected and saved to represent crops in good, average or poor seasons to enable a comparison of the results of liming with varying seasons.

Select the rates of fertiliser typically applied to the crop. Only nitrogen fertiliser is considered, as it may have a direct acidifying effect and is related to nitrate leaching. Nitrogen in the form of ammonium (i.e. ammonium sulphate, seeding NP-compound) causes acidification due to the net addition of acid when ammonium is converted to nitrate. Nitrogen added in the form of urea or UAN is not directly acidifying. However, acidification will occur proportionally with the leaching of nitrate derived from any nitrogen fertiliser or legume-fixed nitrogen.

Each 'crop' is assigned an 'acidity tolerance class', ranging from 1 (most tolerant) to 8 (most sensitive). For the default crops, the acidity tolerance class is 2 for lupin, 3 for wheat, oat, hay and pasture and 5 for barley, canola and pulse. New crops can be generated from these defaults.

Rotation

Crops and/or pasture may be selected to form a rotation. The sequence of the crops and pastures selected is repeated over 20 years.

In iLime, the fallow option is essentially a lack of crop with no income nor nitrogen fertiliser. There are no implications for soil water nor nitrogen for crops following a fallow in this model.

Strategy

Lime quality data are represented by particle size distribution and neutralising value in the same manner as the Lime WA Product Information sheets (http://www.limewa.com.au/). Default values for named limes are from audit samples collected under the Agricultural Lime Industry Code of Practice (http://www.limewa.com.au, accessed 28/05/2019 for iLime version 1). These values are indicative and may be replaced with more recent tests from suppliers or tests of your own samples. On-farm lime can be evaluated with iLime by entering values into the same five sieve categories.

The cost of spreading lime per tonne is simply multiplied by the rate. Therefore the cost used may need to be adjusted if relatively high or low tonnages are used.

Lime may be incorporated to 20 cm or to 30 cm. For simplicity, the proportions of lime incorporated to each of the depths has been fixed. If incorporation to 20 cm is selected, lime is distributed in 0–10 cm and 10–20 cm on a 50:50 per cent basis. For incorporation to 30 cm the distribution used is 25:50:25 per cent over the three soil layers. These estimates have been derived from Scanlan and Davies 2019 (who would suggest less mixing) and Ucgul et al. 2019 (who would suggest more mixing).

Scanlan C & Davies S (2019). Soil mixing and redistribution by strategic deep tillage in a sandy soil. Soil and Tillage Research, 185, 139–145.

Ucgul M, Saunders C, Desbiolles J, Davies S & Parker W (2019). Improving the effectiveness of soil amelioration by optimising soil machine interaction. Presented at the 2019 Agribusiness Research Updates, 25–26 February 2019, Grains Industry Association of Western Australia.

Key calculations

The main calculations in iLime are described below. Details of the mathematical equations may be found in the documentation for Optlime.

Gazey C (2008), Optlime, a bioeconomic model of soil acidity management in agricultural systems. Department of Agriculture and Food, Western Australia, Perth. https://researchlibrary.agric.wa.gov.au/pubns/50/

Lime quality

The % weight and NV % in each sieve fraction for each lime source is used to calculate the surface area of pure lime ($CaCO_3$) per tonne of product.

The average diameter for each sieve range is multiplied by the % weight to calculate the number of particles in that sieve fraction. The number of particles is then multiplied by the surface area and NV % to calculate the total surface area of $CaCO_3$ in that fraction. This is repeated for each sieve range and the values are added together to calculate the total surface area of $CaCO_3$ that can react in the soil over time.

Dissolution of lime is dependent on the current pH of the layer relative to the equilibrium pH for lime dissolution (which is set at 7.5), the pH buffering capacity of the soil and a soil water scalar that varies with the month of the year and the rainfall zone. The total amount of lime dissolved in each layer is summed over months of the year and the sieve ranges.

Acidification rate

The addition of acid to the soil comes from the removal of alkaline product (carbon source), acidifying ammonium-based nitrogen fertilisers and leaching of nitrate (nitrogen sources).

Removal of alkaline product for each scenario in each year is calculated by multiplying the yield for that scenario/year by the average alkalinity removed per tonne of crop or kg of pasture (via stock, as DSE).

Nitrogen sources contribute to acidification due to acid produced during mineralisation and nitrification and/or nitrate leaching. Mineralisation and nitrification of nitrogen sources may contribute net acid to the soil. In iLime this is included as the equivalent lime required to neutralise the acid produced per kg of nitrogen applied as that source (i.e. 3.6 kg lime per kg N for seeding NP-compound or ammonium sulphate and 0 lime per kg N for urea, UAN and legume). Acidification due to nitrate leaching is calculated from the product of the potential acidification if all of the nitrogen derived from the nitrogen source is leached (3.6 kg lime equivalent per kg nitrogen) and the leaching percentage. The leaching percentage is based on the soil texture and rainfall zone (Table 1).

Table 1 – Leaching percentage for combinations of soil texture and rainfall zone used in the model.

Rainfall zone	Sand	Sandy loam	Loam	Clay-loam	Clay
< 325 mm	50	30	10	0	0
325–450 mm	65	45	25	5	0
450–750 mm	80	60	40	20	0
> 750 mm	95	75	55	35	15

The fertiliser rates specified for each crop are adjusted for yield by multiplying the nominated rate by the yield index.

pH change

The potential change in pH in each layer due to liming is calculated from the total amount of lime dissolved divided by the pH buffering capacity. This change is then added to the current pH of the layer to calculate an interim pH.

The interim pH is adjusted for any lime movement to the next layer. Lime movement only occurs if the pH is above the minimum pH for leaching (pH 5), based on an exponential function that accounts for the difference in pH, soil water content and pH buffering capacity.

The change in pH due to liming is adjusted for annual acidification.

Throughout iLime, the pH is that measured in $CaCl_2$.

Yield

The yield entered for each crop of the rotation is used to calculate a yield not limited by acidity. This represents the yield if the pH of the soil was at the recommended minimum targets of 5.5 in the surface (0–10 cm) and 4.8 in the 10–20 cm and 20–30 cm.

The yield that is reported each year is the yield not limited by acidity multiplied by a yield index. This yield index takes into account the penalty for the soil pH (0–10 cm) and aluminium level in the 10–20 cm and 20–30 cm, adjusted by the acid tolerance of the ‘crop’.

Benefits and costs of liming

Benefits and costs relate only to acidification and liming.

The cost of lime in a year is determined from the rate, cost, spreading cost and cost of incorporation (if any). The benefit of liming is calculated from the yield for the scenario compared to the unlimed.

The cashflow for each scenario is determined from the benefit minus the cost in each year. The benefit and cost in each year is adjusted for the discount rate to produce discounted benefit and cost. Cumulative cashflow is the sum of the discounted cashflow in each year and is also reported as the net present value (NPV).

Return on investment (ROI) is the cumulative discounted cashflow divided by the cumulative discounted cost.

Simplifications and changes to Optlime in iLime

Some simplifications and changes were made to the Optlime model in order to streamline the inputs required for the iLime app.

Bulk density

The bulk density of the soil is used in the calculation of pH buffering capacity and saturated water content (for lime dissolution calculations). Changes in bulk density have little effect over the range of values for soil in southern WA (1.4–1.6 Mg/m^3), so this has been fixed at 1.5 Mg/m^3.

Seeding N fertiliser

Compound nitrogen-phosphorus (NP) fertilisers are formulated using various combinations of mono-ammonium phosphate, di-ammonium phosphate and/or ammonium sulphate. The formulation is not commonly known, hence we have utilised a generic seeding NP-compound fertiliser in iLime. This requires only the input of the proportion of nitrogen in the product (which is generally known).

Acidification from this fertiliser is set at 3.6 kg lime equivalent per kg N applied (7.1 kg lime equivalent per kg N applied if all of the nitrate is leached). This simplification will result in an over-estimation of the acidification resulting from the use of fertilisers with a large proportion of di-ammonium phosphate (DAP) in their formulation, since acid addition from the mineralisation and nitrification of DAP is 1.8 kg lime equivalent per kg N applied.

Potential yield

The calculation of yield in Optlime relied on the specification of a ‘potential yield’ for each crop assuming that acidity was not a limitation. In iLime this has been replaced with a non-acidity limited yield that is calculated from the average yield provided by the user (see ‘Yield’ above).

Discount rate

The discount rate in iLime is set at 7%.

Lime requirement

Calculation of the estimated lime requirement utilises the approach, derived from Helyar and Porter (1989), that was used in the Liebe 'Soil Amelioration Profit Calculator’ (http://www.liebegroup.org.au/liebe-group-publications/lime-profit-calculator/). The lime requirement for each soil layer is calculated using the difference between the target pH (5.5 for 0–10 cm and 4.8 for 10–20 cm and 20–30 cm) and the initial pH of the layer, divided by a conversion factor for soil texture (0.67, 0.57, 0.47, 0.37, 0.26 for sand, sandy loam, loam, clay loam and clay respectively). The calculated value is adjusted for gravel percentage and then summed for the layers. An additional 0.4 t/ha lime (100% $CaCO_3$) is added if the soil organic carbon is above 2%.

Helyar K & Porter W (1989). Soil acidification, its measurement and the processes involved. In A Robson (Ed.), Soil Acidity and Plant Growth (pp. 61–101). Academic Press Australia: Marrickville, NSW.

Credits and contact

iLime was conceived and created by James Fisher, Fiona Evans and Chris Gazey. App design and implementation by Steve Collins and Rhys Davies. The app was developed under GRDC and DPIRD project DAW00236.

iLime implements the Optlime spreadsheet model in an easy-to-use app. Users can generate results with just a few selections and may specify options to suit their circumstances.

The Optlime spreadsheet models the main factors related to soil acidity. It was developed as part of the ‘Time to Lime’ research programme, 1996—2001, using established principles of soil acidity and results from field and laboratory experiments carried out in WA. It was thoroughly reviewed in 2008. iLime has been tested using data collected over the past 10 years (paper in preparation).

Optlime was originally developed by Andrew Sandison and Andrew Bathgate with refinement and spreadsheet design by Michael O’Connell. Contributors: Bill Porter, Perry Dolling, Amanda Miller, Lorelle Lightfoot, Mark Whitten, Eugene Diatlof, Andrew Rate, Zed Rengel, Nicole Glenn, Caixan Tang and Chris Gazey and James Fisher. Concept & equations in the 2008 version: Bill Bowden, Craig Scanlan and Chris Gazey.

Thank you to farmers at many field days, Soils Constraints West steering committee, Kwinana West RCSN members, Garren Knell, Wayne Pluske, Ashton Gray, Graham McConnell, Ashley Herbert, Jeremy Lemon, John Blake, Art Diggle, Gaus Azam, Jenni Clausen, Greg Shea, Caroline Peek, George Mwenda, James Bee, Lucy Anderton, Nathan Dovey, Carla Milazzo and Sarah Belli for initial suggestions and/or feedback.

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