A preliminary examination of the spatial distribution of acidic soil and required rates of ameliorant in the Avon River Basin, Western Australia

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Abstract
Soil acidity is a major constraint to agricultural production in the south-west of Western Australia. This paper will examine a simplistic approach to mapping the spatial distribution of soil acidity in the Avon River Basin (ARB) of Western Australia and discuss the implication this has on liming requirements in this region. Soil pH_{Ca} at 0.1 m intervals to a maximum depth of 0.3 m was analysed at 39480 locations across the ARB. The geo-location of these samples was recorded and soil pH_{Ca} distribution mapped using soil-landscape polygons. Nearly seven million hectares of topsoil (0–10 cm) is estimated to be extremely to moderately acidic (pH_{Ca} 4.3–5.5) and nearly four million hectares of shallow subsurface (10–30 cm) is estimated to be extremely to highly acidic (pH_{Ca} <4.8). At these levels of acidity, it is calculated that the ARB will require nearly twelve million tonnes of agricultural lime to increase the topsoil to pH_{Ca} 5.5 over a shallow subsurface of pH_{Ca} 4.8.

Key Words
Soil acidity, Avon River Basin, spatial distribution, Western Australia.

Introduction

Soil acidity has been shown to constrain productivity in cropping and pasture based agriculture, resulting in reduced plant biomass and lower crop yields (see Gazey and Andrew these proceedings; Hajkowicz and Young 2005). This reduction in plant biomass has financial consequences for growers and can lead to adverse and unsustainable events such as water and wind erosion, dryland salinity and loss of soil organic carbon. Current estimates of acidity in Western Australia may not accurately represent the extent of soil acidity in regions such as the ARB.

This paper uses an existing soil database to more accurately quantify the current spatial extent and severity of soil pH_{Ca} of the ARB. Data used in this paper have only recently become available hence data analysis is still in the preliminary stages. The data are extracted from a three-year project, which was finalised in September 2009. Soil pH_{Ca} distribution maps and associated liming recommendations were completed in mid October 2009. It is planned that more detailed analysis will be carried out in the near future.

Methods

Data collection and analysis

Soil pH_{Ca} data used in this study were collected, and are held by, the commercial soil sampling company Precision SoilTech. All pH values presented were measured in 1:5 soil:0.01 M $CaCl_2$. The samples were collected between 2000 and 2006 as part of Precision SoilTech's commercial operations and between 2007 and 2009 as part of a project in partnership with the Department of Agriculture and Food, Western Australia and the Avon Catchment Council (Gazey and Andrew 2008; Gazey and Andrew 2009). Soil samples were collected using Precision SoilTech sampling machines, which consist of a vehicle-mounted vacuum system to lift samples from the soil profile. All samples were collected using the same sampling method of bulking 10 cores over a 3 m x 10 m area at each sampling location. Each location was recorded using a Rinex Saturn HBox guidance computer in datum GDA94.

Spatial analysis

Soil-landscape map polygons developed by Schoknecht, Tille and Purdie (2004) were used to produce soil pH_{Ca} distribution maps. Sample geo-location, soil pH_{Ca} and soil-landscape polygons were viewed and intersected using Geomedia (Intergraph). The average soil pH_{Ca} was calculated at each soil-landscape polygon for each sampling depth (0–10 cm, 10–20 cm and 20–30 cm). Not all soil-landscape polygons contained sampling locations. Those polygons that did contain sites were given the average pH_{Ca} of the samples collected within it and were termed 'Level 1' polygons. Those that did not contain sampling locations, though were part of a collective soil-landscape unit or sub-system (see Schoknecht, Tille and Purdie 2004), were given the average soil pH_{Ca} of all the points that were contained within that sub-system and termed 'Level 2' polygons. If no sampling locations were contained by any polygon that made up a sub-system it was given a 'null' value (Figure 1). The resulting Table was joined to the soil-landscape polygon feature and thematic layers created (Figure 2).

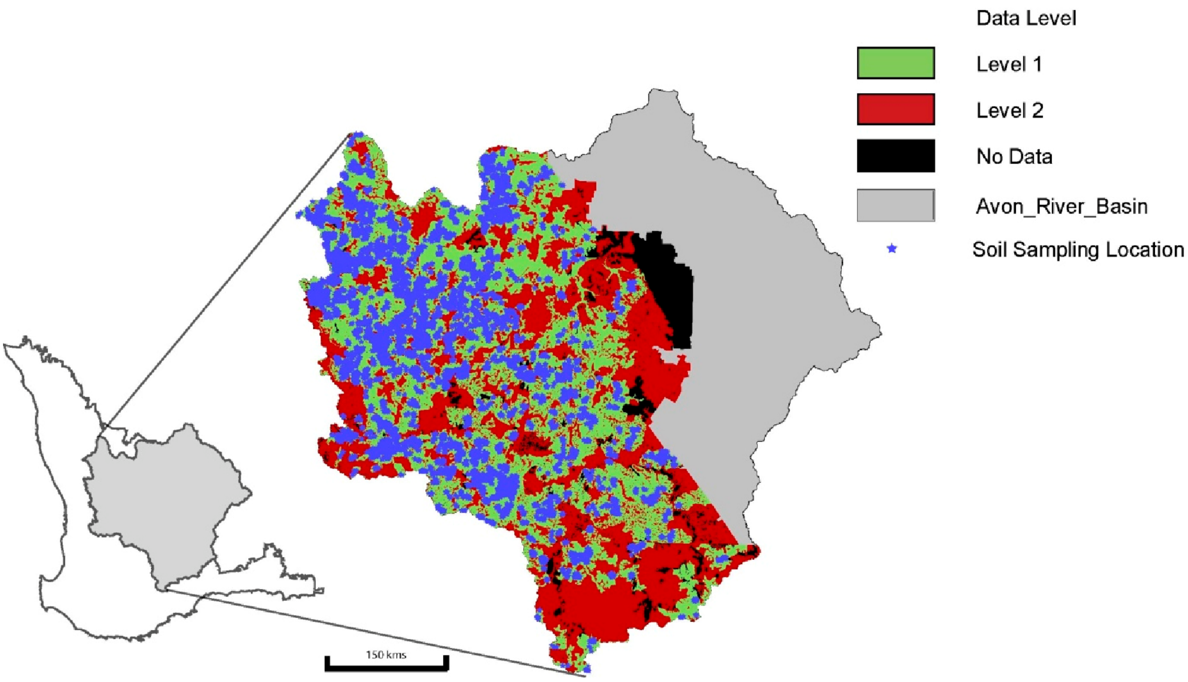

Figure 3. The Avon River Basin of Western Australia showing the soil pH_{Ca} sampling locations used in this study. Coloured polygons represent the various polygon levels of data.

Liming recommendations

Liming recommendations were developed for each individual polygon based on the soil pH_{Ca} of each sampling layer available. As not all polygons had shallow sub-surface (10–20 cm and/or 20–30 cm) pH_{Ca} information recorded, three separate liming recommendation calculations were used (Table 1). The soil acidity management tool Optlime (O'Connell 2008) was used to assess the suitability of these calculations.

Table 1. Liming recommendations for individual soil-landscape polygons were calculated using the following criteria. A simple formulae was used which summed the pH_{Ca} values for each polygon. As not all polygons had soil pH_{Ca} information collected at each depth, there are three formula that were used. i) 0–10 cm pH_{Ca} data only, ii) 0–10 cm and 10–20cm only, iii) 0–10 cm and 10–20cm and 20–30 cm data available.

Calculated lime requirement (t/ha)	Criteria for given lime requirement based on pH_{Ca} data available		
	IF 0–10cm only	$\sum pH_{Ca}$ (IF 0–10 cm + 10–20 cm only)	$\sum pH_{Ca}$ (0–10 cm + 10–20 cm + 20–30 cm)
0	> 5.9	> 12.0	> 16.8
1	> 5.3	> 10.2	> 14.9
2	> 4.8	> 9.90	> 14.2
3	> 4.6	> 8.40	> 13.4
4	>3.86	>7.90	> 12.4
5	-	> 7.5	> 11.4

Results

Soil pH_{Ca} distribution in the Avon River Basin

The vast majority of the topsoil in the Avon River Basin has been estimated to be acidic (pH_{Ca} <7) and is widespread across the entire Avon River Basin. Almost 80% of the 0–10 cm soil layer is pH_{Ca} <5.5 with over 11% pH_{Ca} <4.8. Less than 1% of the soil area was estimated to be neutral or alkaline (Table 2). Soil acidity is not restricted to any particular soil group, though any light textured soil (Sandy Duplex, Duplex Sandy gravel, Yellow Sandy Earth) is generally acidic. Areas of higher pH_{Ca} are generally found in the eastern regions of the ARB and are dominated by the Saline Wet and Calcareous Loamy Earth soil groups (Figure 2a).

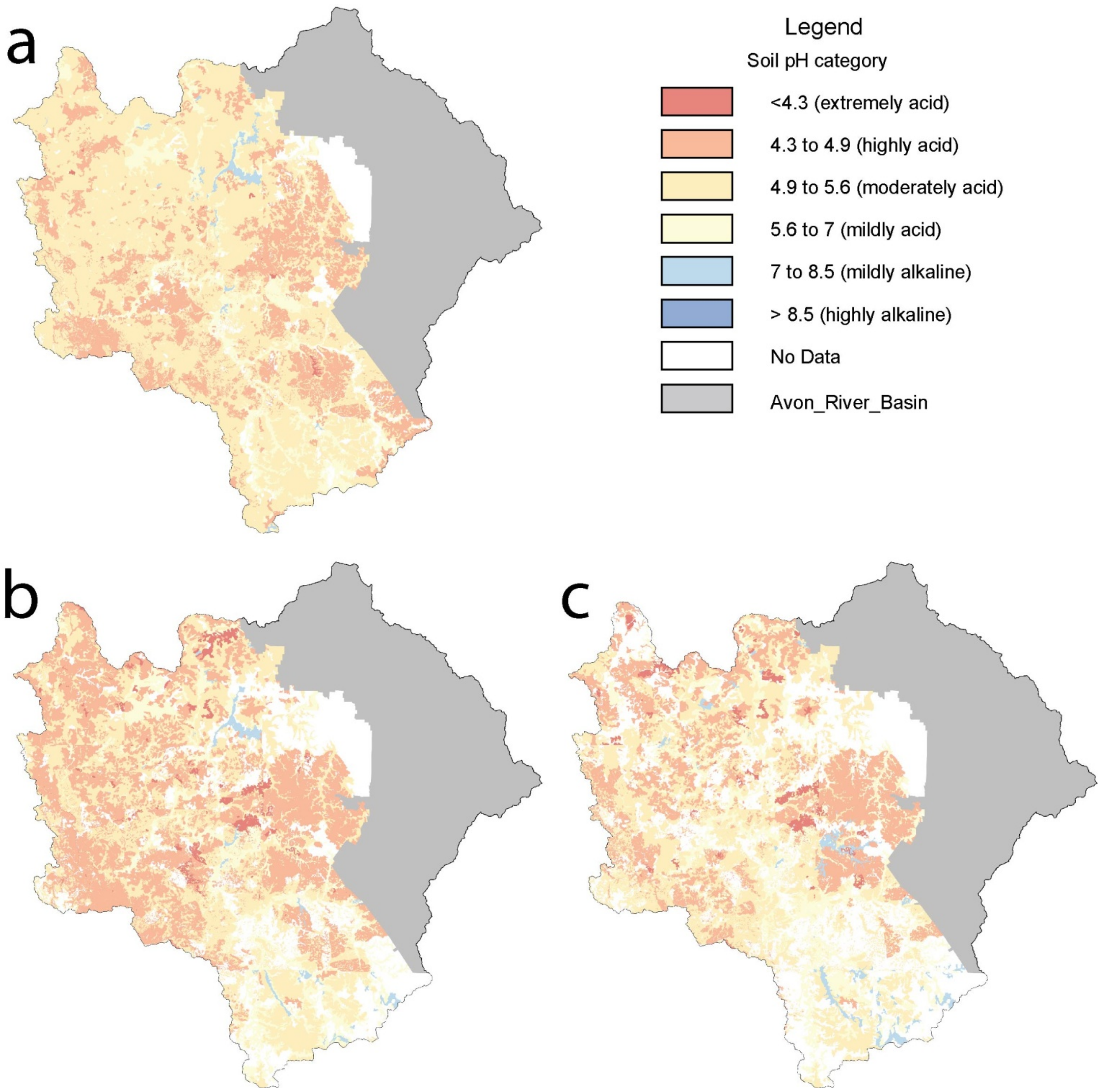

Figure 4. Soil pH_{Ca} distribution for the 0–10 cm (a), 10–20 cm (b) and 20–30 cm (c) soil layers in the Avon River Basin.

Soils that are acidic in the topsoil are generally acidic in the shallow subsurface, although there were also many areas with moderate to mild levels of acidity in the topsoil which had high or extreme acidity in the shallow subsurface (Figure 2b & 2c). An overall decrease in the area of acidic soil in the shallow subsurface was predicted, though the level of acidity is more severe with twice as much soil with pH_{Ca} <4.8 than in the topsoil.

Avon River Basin lime requirement

It is calculated that 11.7 M tonnes of agricultural lime will be required to ameliorate the levels of acidity present in the Avon River Basin (Table 2). This requirement is based on the application of a fine, ~90% $CaCO_3$ lime, as this is available to growers in the ARB. It is encouraging that over 92% of soil area in the ARB can ameliorated with approximately three tonnes per hectare of lime or less.

Table 2. Summary of the severity and extent of soil acidity in the Avon River Basin. Soil acidity classifications are based on the National Land and Water Resources Audit (2001).

NLWRA Category	Topsoil (0–10 cm)		Midsoil (10–20 cm)		Subsoil (20–30 cm)	
	Area (Ha)	% of area in ARB	Area (Ha)	% of area in ARB	Area (Ha)	% of area in ARB
extremely acid (< 4.3)	8,830	0.1	149,370	1.8	129,659	1.6
highly acid (4.3–4.8)	969,046	11.6	1,896,884	22.8	1,370,132	16.5
moderately acid (4.8–5.5)	5,504,830	66.1	3,167,187	38.0	2,637,569	31.7
mildly acid (5.5–7.0)	1,129,860	13.6	1,219,923	14.6	1,266,682	15.2
mildly alkaline (7.0–7.7)	45,333	0.5	59,274	0.7	98,259	1.2
moderately alkaline (7.7–8.5)	32,608	0.4	30,980	0.4	52,905	0.6
highly alkaline (>8.5)	0	0.0	0	0.0	0	0.0
No Data	638,266	7.7	1,805,157	21.7	2,773,568	33.3
Total	8,328,773	100	8,328,773	100	8,328,773	100

Table 3. Calculated agricultural lime requirements to treat current levels of acidic soil in the Avon River Basin.

Estimated lime recommendation (t/ha)	Soil area (ha)	Required amount of lime (tonnes)
0	1,231,017	0
1	2,957,559	2,957,559
2	1,895,819	3,791,637
3	1,384,286	4,152,857
4	220,751	883,005
5	1,076	5,380
No Data	638,266	-
Total	8,328,773	11,790,438

Conclusion

This preliminary examination indicates that soil acidity is widespread throughout the ARB and is at, or approaching, levels likely to cause losses in agricultural production. In many situations, it is estimated that a 1–4 t/ha application of lime will ameliorate present topsoil and/or subsurface soil acidity, and ongoing liming will be needed to counteract ongoing acidification. The profitability of liming, amount of lime needed and period of time required to ameliorate acidity, should still be assessed by individual land managers.

This study highlights the potential for further analysis to be conducted on agricultural regions to the north and south of the Avon River Basin.

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