Can soil change be assessed for the Victorian dairy industry?

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Abstract. Meeting the increased demand for dairy products will require careful management of soils to minimise land degradation and sustain increased production. Key to providing farmers with the tools to manage their soils sustainably, is firstly understanding the soil types currently managed by dairy farmers, and secondly quantifying changes in soil properties in response to management. The Victorian Land Use Information System was interrogated to identify dairy land parcels and these data overlaid on soil survey information to identify the dominant soil Orders managed by dairy farmers in the three dairy regions of Victoria. Of the approximately 590,000 hectares of dairy land identified across the state, Sodosols (33%), Chromosols (20%), Dermosols (16%), and Vertosols (11%) are the major soil Orders represented, although the dominant soil Orders vary for each region. Legacy data from research and extension activities undertaken between 1995 and 2010 were collated to understand regional differences in dairy soil properties. All soil properties were significantly and positively skewed with higher median pH, EC and available K in northern Victorian soils. Further analysis compared the 1995 to 2010 data with data from samples analysed by the government analytical laboratory between 1973 and 1980 to assess any differences over 38 years. The older soil chemical data were also positively skewed but had lower median soil pH, Olsen P and available K, consistent with the greater use of inputs by the industry in more recent years.

1. Introduction
The Australian dairy industry like other agricultural sectors is responding to increasing world demand for food [1], especially as the economies of countries with traditionally lower gross domestic product improve and diets include more animal protein. While dairy farms have intensified production [2] a major competitive advantage of the industry remains the relatively low cost of producing permanent pasture. A number of farm management practices have the potential to degrade soil condition and therefore reduce plant growth and compromise animal health. These include how nutrients and forage are applied and utilised, and nutrient redistribution through regular on-farm movement of dairy cows. For example, the dairy industry has increased its use of fertiliser, feed and effluent nutrients over the past 20 years with average use of N, P, K and S fertiliser of 96, 30, 63, and 26 kg ha⁻¹ respectively, but up to 424, 82, 177, and 85 kg ha⁻¹ respectively applied on some farms [3]. Cows can deform soils due to the size and weight of the animal [4], and the nutrient content of their excreta will affect soil chemical and biological properties [5, 6]. To help ensure that dairy production systems are sustainable, managers require knowledge of a) soil types and properties b) the condition of the soils.
and c) the impact of practices. This paper describes the approach taken to meet the first two requirements and discusses the implication of the results.

2. Material and Methods

2.1 Victorian dairy soil types

The Victorian Land Use Information System (VLUIS) database which provides spatial coverage of land use across Victoria [7] was used to identify ‘dairy’ parcels within the ‘pasture/grassland’ land cover classification. The dairy parcels were overlaid with available regional and sub-regional soil survey mapping. This mapping varied from detailed soil type mapping (e.g. in irrigation regions) to broader scale soil/landform (1:100 K scale) or land system (1:250 K scale) mapping. The dairy soils identified were grouped according to their dominant soil Orders based on the Australian Soil Classification [8].

2.2 Victorian dairy soil condition

Legacy soil data including unpublished data from Victorian Government researchers and extension staff were collated to provide estimates of dairy soil condition. These data consisted of 4814 records collected from 16 experimental and extension activities undertaken on 297 dairy farms around the state between 1995 and 2010 (Table 1). Additional data from samples collected between 1973 and 1980 were sourced from the Victorian Government soil analytical laboratory database. These data (3738 records), derived from samples collected by Government extension staff from dairy paddocks, were compared with the more recent (1995 to 2010) dataset. Samples had been collected using recommended procedures and accredited analytical methodologies were used.

### Table 1. Experiments from which legacy soil data were sourced.

| Data ID | Dates | Farms sampled | Regions | Reference |
|---------|-------|---------------|---------|-----------|
| A4N     | 2008  | 17 Gi, swV, NV | [9]     |
| MDF     | 2007-2010 | 1 Gi | Lane pers comm. |
| AS      | 2007-2008 | 28 swV | Standish pers comm. |
| HDLN    | 2006-2007 | 24 swV | [10] |
| MRF     | 2005  | 1 Gi | Neilsen et al. pers comm |
| NMP_FSV | 2005-2008 | 142 Gi | Kelsall pers comm |
| HBI     | 2004-2006 | 2 Gi | Gourley et al. pers comm |
| TAR     | 2004  | 4 Gi | Melland et al. pers comm |
| BBF     | 2004  | 2 Gi | Gourley et al. pers comm |
| DSAT    | 2003-2004 | 30 Gi, swV, NV | Neilsen et al. pers comm |
| GDRP-P  | 2002  | 1 Gi | [11] |
| WFN    | 1999, 2002 | 3 Gi | Gourley et al. pers comm |
| NWH    | 1999  | 4 Gi | White pers comm |
| CSOP    | 1998  | 36 Gi, swV, NV | [12] |
| SQ      | 1997-1998 | 1 Gi | [13] |
| PFD     | 1995-2001 | 10 Gi | [14], DEDJTR Research Farmlets |

*Victorian dairy regions: Gi (Gippsland), swV (south-west Victoria), NV (northern Victoria)

2.3 Sample collection and analysis

The soil samples consisted of a minimum of 30 soil cores (2.5 cm diameter x 10 cm depth) collected either randomly throughout a paddock or systematically along a transect considered representative of the paddock. Dried (40°C), and sieved (<2 mm) samples were analysed for pH (in water or 0.01 \( \text{CaCl}_2 \)) and electrical conductivity (EC) at a 1:5 soil:solution ratio. Bicarbonate extractable Olsen P, available K (either by bicarbonate extraction – Colwell K, or hydrochloric acid - Skene K), and S (KCl\textsubscript{40}-S) were analysed. Details of the methods are provided in Rayment and Lyons [15].
2.4 **Statistical analysis**
The soil order data were summarised to give percentages of each soil type. Legacy data were analysed to quantify chemical properties of soils under dairy management. Summary statistical analysis was initially carried out using Genstat 14.1 (VSN International) to calculate the mean, median, minimum, maximum, standard deviation and coefficient of variation. The data were also analysed to assess regional (Gi – Gippsland, NV – northern Victoria, swV – south- west Victoria) soil differences using REML analysis, and to compare past (1973 to 1980) and more recent (1995 to 2010) soil properties.

3. **Results and Discussion**
The Victorian dairy industry is approximately evenly distributed in three regions; northern Victoria, Gippsland and south- west Victoria, based on dairy farm post code data (Figure 1, Table 2, [16]). The soil types in each region are likely to influence soil properties and therefore recommended soil management practices.

**Table 2.** Numbers (and percentages) of Victorian dairy farms (2011/2012), legacy research and extension (1995-2010) and analytical (1973-1980) data for Gippsland (Gi), northern Victoria (NV) and south-west Victoria (swV) regions.

| Region | Dairy farms | Research and extension records | Government analytical lab records |
|--------|-------------|---------------------------------|----------------------------------|
| Gi     | 1575 (34)   | 2490 (52)                        | 1382 (37)                        |
| NV     | 1551 (34)   | 392 (8)                          | 840 (22)                         |
| swV    | 1454 (32)   | 1932 (40)                        | 1518 (41)                        |

3.1 **Victorian dairy soil types**
A total of 590,000 hectares of land was estimated, using the VLUIS, to be managed by dairy farmers in Victoria. Sodosols (33%), Chromosols (20%), Dermosols (16%) and Vertosols (11%) accounted for 80% of Victorian soils, with the remaining eight soil Orders each comprising less than five percent (data not presented). However, the proportion of major soil Orders varies in each region (Figure 1). For example, Sodosols, the dominant soils in the NV (61%) and Gippsland (19%) regions, only comprise an estimated 9% of the soils managed by dairy farmers in south- west Victoria. The dominant soil Orders reflect characteristics such as sodicity, acidity and degree of texture contrast that will affect their response to typical farm management practices as well as influence how these soils should best be managed to minimise their chemical and physical constraints to pasture and fodder production and grazing management. In addition to regional differences in dominant soil orders, the proportion of Sub-orders also vary within each region. For example, Black Dermosols are more common in the eastern part of Gippsland (alluvial plains) compared with Brown Dermosols to the west in the rolling hills. These differences also influence soil characteristics such as depth of topsoil and friability.
3.2 Victorian dairy industry

Legacy research and extension data were available from all regions with the majority (52%) from dairy farms in Gippsland and only 8% from northern Victoria (Table 2); this distribution reflecting the location of the research and extension groups and programs as well as the relative priority placed on irrigation rather than nutrient management in northern Victoria. Soil chemical properties were significantly skewed with higher median soil pH, EC and available K in northern Victoria; most likely influenced by the dominant soil orders in that region (Table 3, Figure 2a). Significant ($P<0.04$) region and farm differences and non-significant paddock differences were observed for soil properties.
Table 3. Summary statistics of 4814 records of legacy chemical data from soil samples collected on dairy farms in all three regions in Victoria between 1995 and 2010.

| Soil property | No. of samples | Minimum | Mean | Median | Maximum | Std Dev | CV (%) | Skew |
|---------------|----------------|---------|------|--------|---------|---------|--------|------|
| pH (H₂O)     | 4156           | 4.5     | 5.7  | 5.6    | 8.4     | 0.50    | 9      | 0.95 |
| pH (CaCl₂)   | 3576           | 3.8     | 5.0  | 5.0    | 8.1     | 0.54    | 11     | 1.13 |
| EC (dS m⁻¹)  | 3615           | 0.02    | 0.18 | 0.14   | 7.31    | 0.218   | 120    | 17.995 |
| Olsen P (mg kg⁻¹) | 4814   | 3   | 38   | 33    | 711     | 27.6    | 74     | 8.5  |
| Avail K (mg kg⁻¹) | 4814 | 39  | 319  | 270   | 11000   | 334.5   | 105    | 17.8 |
| S₂Cl₄-40 (mg kg⁻¹) | 4397 | 2   | 19   | 15    | 810     | 23.6    | 122    | 16.2 |

The 1973 to 1980 legacy data were more uniformly distributed around the state in line with the distribution of dairy farms (Table 2). As with the 1995 to 2010 data, soil chemical properties were also positively and significantly skewed (data not presented). However, median soil pH, K, and Olsen P from the earlier samples were lower than that from 1995 to 2010. These differences are mostly likely due to the greater use of inputs by the industry recently (Figure 2b,c, [3]).

Figure 2. Soil pH and EC (dS m⁻¹) (1:5 soil: water) and available K (mg kg⁻¹) for soils sampled on Victorian dairy farms between a) 1995 and 2010, b) 1973 and 1980, and c) Olsen P (mg kg⁻¹) data from the same two time periods for the Gippsland (Gi), northern Victoria (NV) and south-west Victoria (swV) regions. Horizontal red lines indicate agronomic optimum levels.
4. Conclusions
The dominant soil orders identified for each dairy region can be used as a basis for developing region-specific soil and farm management guidelines and programs for the industry. Analysis of legacy data has been used for understanding soil change more broadly in Victoria [17], and in this paper industry specific legacy data were investigated to understand regional and temporal differences in soil properties. While legacy data can be used to inform priority farm management and policy decisions and to strategically target soil monitoring resources, data analysis and interpretation needs to be mindful of sample collection and analytical methods and fit for purpose sampling.

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