Evaluation of surface soil condition in Tasmania, Australia

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Abstract
Soil condition information has been collected for 272 sites across Tasmania. Soil target values were developed for six key soil condition indicators, with values dependent on Soil Order and land use which allowed for evaluation of soil condition. Soil condition monitoring sites were biased to agricultural land uses, which was justified due to these land uses being more likely to result in soil degradation than conservation or native forestry. Cropping and perennial horticulture land uses had a greater proportion of sites outside targets for organic carbon and bulk density than grazing pasture and forestry. Soil pH was of concern under pasture grazing and organic cropping but most intensively used soils were within pH targets. Aggregate stabilities at many sites were outside targets under cropping and irrigated pasture. Extractable Phosphorus levels were below target for many dryland pasture sites and above target for many irrigated pasture sites.

Key Words
Targets, soil order, land use.

Introduction
Monitoring soils over the medium to long term is the only way to measure the magnitude and direction of change in soil properties arising from human and natural influences, and so monitoring is a fundamental requirement for assessment of soil sustainability. Both Soil Order and land use type are useful criteria for explaining the variability of soil properties used to measure soil condition (Sparling *et al*. 2004). An important aspect of monitoring soil condition is setting target values for different soils and land uses in order to be able to evaluate results. The soil condition evaluation and monitoring (SCEAM) project commenced in 2004 and is designed to provide the means to assess the impact of land management on soil condition and allow for improved soil management decision making and investment to improve sustainability.

Methods
Selected sites were chosen depending on where physical investigation had identified required soil orders with appropriate land use, regionally typical and spatially uniform soil profile characteristics were represented, and the land owner was cooperative (Figure 1). Twelve Soil Orders were represented and land use was divided into seven categories including conservation, dryland pasture, irrigated pasture, native forest, plantation forestry, intensive cropping and perennial horticulture. The representativeness of Soil Orders and land uses in the SCEAM data set was estimated by comparing the frequency of sampling against the mapped area of each Soil Order and land use from published information (Cotching *et al*. 2009; Bureau of Rural Sciences 2003).

Full land use history was recorded for each site. A soil pit was excavated at each site to 1.2m depth (where possible) for full description and classified to Family level. Samples were collected from each major layer within the soil with samples from any single layer bulked over a maximum 300 mm depth range. Samples were also collected by hand auger and bulked from every 2 m along a 50 m transect for both surface (0 to 75mm) and sub-surface horizons (75mm thickness cores between 75 and 300mm depth, depending on horizon depths), and chemically analysed by CSBP Wesfarmers laboratories for exchangeable cations (Ca, Mg, Na, K), exchangeable acidity, Aluminium, Hydrogen, pH (water 1:5), pH ($CaCl_2$), EC (water 1:5), Phosphorus (Colwell, Olsen), Potassium (Colwell), Boron, Copper, Iron, Manganese, Sulphur, Zinc, organic carbon (OC), total Nitrogen, ammonium and nitrate Nitrogen, and reactive Iron, (Rayment and Higginson 1992). Soil cores were collected from both depths using stainless steel cylinders (75 mm long and 75 mm in diameter) for determination of bulk density. Bulk samples were collected for determination of aggregate stability.

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There is a body of knowledge already existing in Tasmania that includes a soils database held by the Department of Primary Industries Parks, Water and Environment, published information on soil properties under a range of land uses, plus expert knowledge based on experience of farmers' soil tests and trial results. This body of knowledge was drawn on, together with the results of SCEAM project to produce a set of soil targets. Soil target values were developed for six key soil condition indicators, with values dependent on soil order and land use. The selected indicators were: pH (H_2O) as an indicator of soil acidity; organic carbon as an indicator of organic matter and biological activity; Phosphorus (Olsen) as an indicator of nutrient depletion or enrichment; exchangeable Sodium, bulk density and aggregate stability as indicators of structural condition.

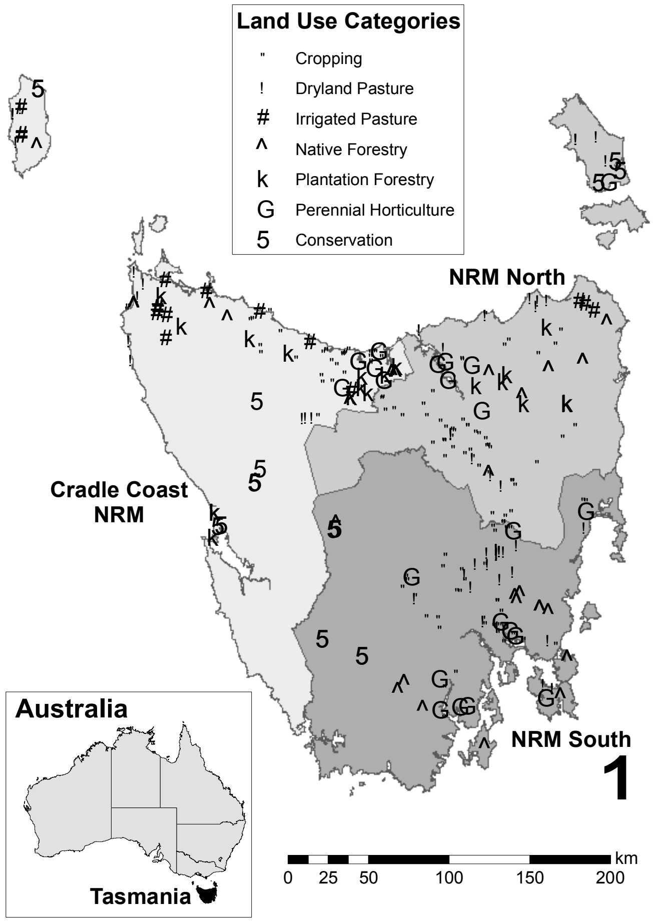

Figure 1. Site locations for soil condition evaluation and monitoring in Tasmania.

Results and discussion

The frequency of sampling in the SCEAM dataset was biased to those soil/land use combinations of concern compared with the mapped distribution of Soil Orders and land uses in Tasmania. Ferrosols, Sodosols and Vertosols were over represented whereas Kurosols, Organosols and Rudosols were under represented. The rate of sites sampled over the whole of Tasmania is one site per 24 000 ha on average, with a concentration in the northern and eastern areas (Figure 1), where agricultural land use predominates. The more intensive land uses were sampled at the expense of conservation, dryland pasture and native forestry. This is a reflection of concern over current land use trends which are for greater intensification of use and the more intensive the land use, the greater is the likelihood for soil damage.

The current targets for specific soil order/land use combinations in Tasmania (Table 1) have been set for sustainable productive agriculture but it is recognised that targets for environmental outcomes may be different. Other regions in Australia will need to develop their own targets that relate to local soil/land use/climate combinations. Some grazing sites (20 % state-wide) and organic cropping sites (23% state-wide) were outside pH targets (Table 2), but acidity has mostly been addressed by Tasmanian farmers applying locally sourced lime or dolomite. However, at some sites pH targets have been exceeded indicating that these farmers can reduce amendment inputs. The proportion of sites not meeting surface OC targets state-wide

Table 1. Targets for soil condition indicators in Tasmania.
Surface = 0-75 mm; subsurface = 75mm thick sampled between 75 mm and 300 mm

Soil property	Soil order	Land use categories	Depth*	Annual rainfall (mm)	Target value or range
Soil pH(water)	Calcarosols Chromosols Vertosols Dermosols	Pastures	Surface		5.5 – 7.0
		Cropping & Horticulture	Subsurface		5.2 – 7.0
	Ferrosols Hydrosols Kurosols Podosols Sodosols Tenosols	Forestry	Surface + subsurface		4.0 – 7.0
Organic Carbon (% w/w)	Calcarosols Chromosols Kurosols Podosols Sodosols Tenosols	All	Surface		> 2
			Subsurface		> 1
	Dermosols Ferrosols Hydrosols	Cropping & Horticulture	Surface	> 800	> 3
				< 800	> 2
			subsurface	> 800	> 3
				< 800	> 1.5
		Pastures & Forestry	Surface + subsurface	> 800	> 4
				< 800	> 2
	Vertosols	All	Surface		> 4
			Subsurface		> 3
Extractable Phosphorus (Olsen P mg/kg)	All	Pastures	Surface		23 - 28
Bulk density (Mg/m^3)	All	All	Surface + subsurface		< 1.2
Aggregate stability (% > 0.25 mm)	Ferrosols Vertosols	All	Surface + subsurface		> 70
	Calcarosols Dermosols Hydrosols	All	Surface + subsurface		> 60
	Chromosols Kurosols Podosols Sodosols Tenosols	All	Surface + subsurface		> 40
	Rudosols	All	Surface + subsurface		> 30
Exchangeable Sodium percent (ESP)	All except Organosols	All	Surface + Subsurface		< 6.0

Table 2. Proportion of sites not meeting soil condition targets in Tasmania (surface samples)

Land Use Category	pH	Organic carbon	Extractable P	Exchangeable Sodium %	Bulk density	Aggregate stability
Dryland Cropping	0	0	n/a[1]	0	0	0
Dryland Grazing/ Pasture	20	8	50	12	2	15
Intensive Cropping	4	32	n/a	7	12	28
Irrigated Pasture	6	0	56	6	6	25
Native Forest	0	17	n/a	3	3	10
Organic Cropping	23	8	n/a	8	0	38
Perennial Horticulture	5	23	n/a	0	23	19
Plantation Forestry	0	26	n/a	16	0	0
Conservation	n/a	n/a	n/a	n/a	n/a	n/a

[1] No appropriate target applies

shows that 32% of intensive cropping sites and 23% of perennial horticulture sites are below targets and potentially under stress. Forestry sites below OC targets (26%) could be due to sampling post-harvest following soil disturbance. Approximately half of the pasture sites are not meeting extractable Phosphorus targets with dryland grazing sites being below target, which is likely to be inhibiting pasture production, and irrigated pasture above target (data not shown), which could be leading to off-site nutrient enrichment in waterways. Soil sodicity (exchangeable Sodium percent) is of concern in surface soils under dryland pasture grazing (12%), particularly in the Northern NRM Region where Sodosols are concentrated. This indicates that management with gypsum amendments could give positive results. Perennial horticulture and intensive cropping failed to meet surface bulk density targets at 23% and 12% of sites state-wide respectively. Surface soil aggregate stability was below targets for organic cropping (28%), intensive cropping (28%) and irrigated pasture (25%) state-wide, particularly in the Cradle Coast NRM Region.

Conclusions

Soil condition information has been collected for 272 sites across Tasmania. Soil target values were developed for six key soil condition indicators, with values dependent on Soil Order and land use. The set targets allowed for evaluation of soil condition which may trigger responses in management or investment, but these targets are likely to be different for other regions depending on inherent soil and climate characteristics. Soil condition monitoring sites were biased to agricultural land uses, which was justified due to these land uses being more likely to result in soil degradation than conservation or native forestry. Cropping and perennial horticulture land uses had a greater proportion of surface soil samples outside targets for organic carbon and bulk density than grazing pasture and forestry. Surface soil pH was of concern under pasture grazing and organic cropping but most intensively used soils were within pH targets. Surface aggregate stabilities at many sites were outside targets under cropping and irrigated pasture indicating that cropping sites have an increased risk of erosion. Extractable Phosphorus levels were below target for many dryland pasture sites and above target for many irrigated pasture sites.

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