Soil properties as a guide for specific adaptations to climate change

Gregory H. Reid

Natural Resource Advisory Services, NSW Dept of Industry and Investment, Bruxner Highway, Wollongbar, NSW, 2477, Australia
greg.reid@industry.nsw.gov.au

Abstract
Climate change is impacting eastern Australia particularly in relation to the intensity and frequency of rainfall in some seasons. In a training program to assist adaptation by landowners it was found that some soil properties were critical in the selection of specific response strategies. In 46% of the 430 soils tested the rainfall infiltration rate was sub-optimal, reducing the penetration and increasing the run off from storm events. Specific responses to this limitation were guided by calcium/magnesium ratios, compaction and soil carbon. In 32% of locations sub-soil acidity was limiting root depth and the capacity of pastures to withstand dry periods. Exchangeable aluminium was an important factor in determining the appropriate remedies or adaptations. Soil Carbon was low in 28% of the soils and restricting the available moisture holding capacity. This problem had added importance in light of potential carbon trading and specific responses were influenced by infiltration, acidity, cation exchange capacity, and nutrient status. In all cases the final management recommendations were informed by a landscape key reflecting the potential vulnerability of each location to reduced soil moisture.

Introduction
In eastern Australia there is already evidence of an increasing incidence of hot days in spring and an increasing probability of inadequate rainfall in late winter and early spring. Models of climate change forecast that this trend will continue and that rainfall will be more intense and confined to fewer events (Pierce 2007). Adapting to this change requires that landowners attempt to optimise the amount of available soil moisture resulting from infrequent rain falling more heavily.

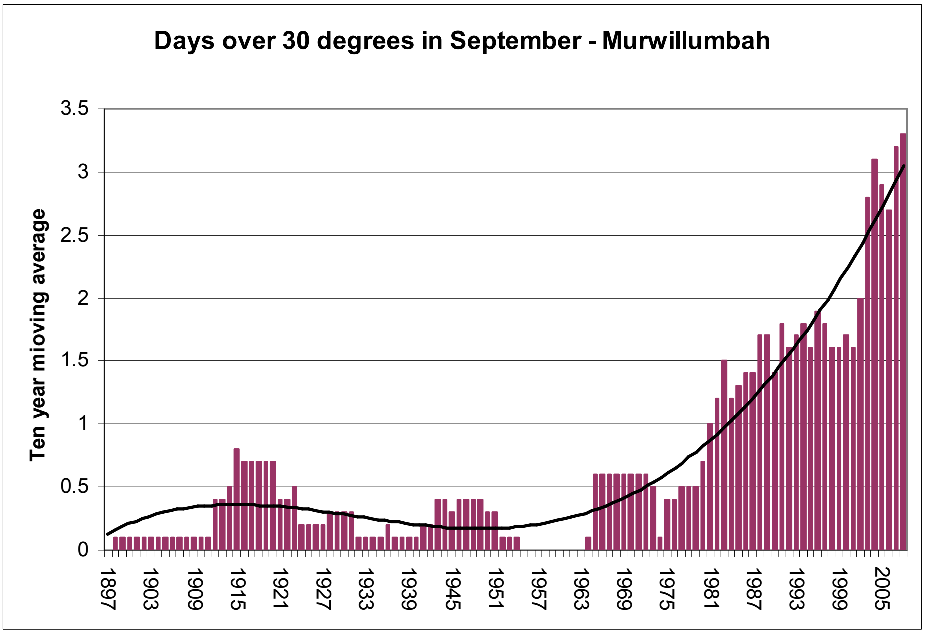

Figure 1. Incidence of hot days in early spring (September) at Murwillumbah in eastern Australia. Sourced from SILO patch point data provided by the Australian Bureau of Meteorology.

The soil moisture available to plants is limited by infiltration rate, root depth, soil texture and soil carbon (Rawls *et al.* 2003). Except for texture, each of these properties can be influenced by particular soil conditions such as compaction, dispersion and sub-soil constraints. These conditions can be diagnosed through related soil properties. Landscape is also influential to available soil moisture. Infiltration rate will be more limiting on steeper gradients where more of the rainfall is shed as run off. Root depth is more critical where the water table is low, for example in deep draining soils or elevated parts of the landscape.

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Soil moisture is also affected by evaporation rate which in turn is influenced by aspect and exposure to dry wind quadrants. A training program was designed which used landscape and soil properties to identify limitations to available soil moisture and appropriate remedies or adaptations. The program was delivered to 330 landowners in locations across several climatic zones in the state of New South Wales, Australia.

Methodology

Landowners received training in the observed and projected impacts of climate change in their area. The landowners collected soil samples and performed simple field tests. Laboratory tests were performed on the samples and these results were read in association with the field results. Aerial plans from Google Earth or other mapping services were used to categorise the landscapes within each farm into a "Drying Order" reflecting relative vulnerability to reduced rainfall (Reid 2009). The landscape and soil properties were combined to identify priority limitations of available soil moisture and to recommend the most cost effective remedy or adaptation.

Results

Field infiltration was found to be less than 10mm/min in 46% of the soils tested. In a few cases this was due to temporary saturation of the soil and this was identified by the percentage moisture content. In 55% of cases, poor infiltration was associated with dispersion indicators (Calcium /Magnesium ratio less than 2:1 or Exchangeable Sodium Percentage above 4%). Pasture root development was found to be sub-optimal in 26% of cases. Of these instances 32% were linked with sub-soil acidity, 27% with sub-optimal infiltration and 17% with compaction, the remainder commonly attributable to overgrazing. Soil organic carbon was less than 2% in 28% of the soils tested. Of these cases 51% were associated with a pH (CaCl) of 4.7 or less and 38% of cases with a cation exchange capacity of less than 4 cmol/kg. Low organic carbon was accompanied by poor infiltration in 46% of cases. Through deficiencies in major nutrients were common (72% of tested soils) fertiliser amendments were not a first choice remedy in soils with limitations to available soil moisture (98% of soils tested). Recommendations were instead prioritised on a cost/benefit basis to measures which improved the potential moisture availability or which adapted to limited moisture availability. The participating landowners expressed considerable interest in the possibility of benefiting from soil carbon credits. The property planning process helped landowners to identify areas with the potential to improve soil organic carbon at the lowest cost (Jastrow *et al.* 2006). A survey at completion the training showed that a high proportion of the landowners were intending specific changes in management practices (Table 1).

Table 1. Summary of some workshop exit survey results from training workshops aimed at improving potential available soil moisture.

Responses to : As a result of this workshop are you planning any of the following changes in your property management?	Percentage of respondents N=172
Soil aeration	59%
Changes in paddock layout	63%
Changes in pasture species	72%
Management for Soil Organic Carbon	88%
Windbreaks and shelter belts	75%
Changes in grazing rotation	61%
Management for deeper roots	85%
Application of lime	69%

Discussion

Available soil moisture is a primary limitation to growth in Australian grazing systems (Moore *et al.* 1997). In locations where climate change is likely to reduce seasonal rainfall one avenue of adaptation is in measures aimed at optimising available soil moisture (White *et al.* 2003). Priorities in such measures can be guided by related soil properties and landscape factors. An example highlighted in this study was the use of lime to promote root development in acidic soils or to improve infiltration in soils prone to dispersion (Steed *et al.* 1987). Grazing management was another important adaptive response indicated by limitations to soil moisture (Lodge *et al*. 2003).

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