THE INTERACTION OF CROP RESIDUE AND FERTILISER MANAGEMENT AND THEIR EFFECT ON SOIL ORGANIC MATTER, SOIL PHYSICAL PROPERTIES AND SUSTAINABILITY

By

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DECLARATION

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged.

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ABSTRACT

The cultivation and cropping of soils across the Australian grain growing regions has resulted in substantial losses of soil organic matter (SOM). These losses have been accompanied by even greater losses in the active or labile components of SOM. Soil organic matter is an important indicator of sustainable farming systems as it has a central role in all aspects of soil fertility.

The grain growing areas of northern New South Wales and southern Queensland in Australia are predominantly based on vertisol soils that have high water-holding capacities. This characteristic, along with initially high levels of fertility, has allowed reliable crop production on these soils in the past. Crop production systems in this area have increasingly used reduced tillage and the retention of crop stubble to increase soil water storage during the fallow period. Declining soil fertility has increasingly become evident but higher rates of N application have been successful in overcoming declines in grain yield and protein content.

Studying changes in the concentration of soil organic matter due to different management practices requires methods that measure responsive and meaningful soil C fractions against large background concentrations. Changes in labile soil C fractions were measured using oxidation with 333 mM $KMnO_4$. The relative amounts of labile and non-labile C (total C - labile C) were compared to a non-cropped reference soil and used to calculate a carbon management index (CMI).

This study focused on increasing the understanding of crop residue breakdown and the influence of tillage and rotation practices on soil carbon fractions and the physical fertility of vertisol soils from the northern grains region. In the first study, two long-term trials established in 1981 were used to assess changes in soil fertility under different tillage and rotation management practices. The trials were located on a commercial property, "Gabo" near Croppa Creek, and at the Liverpool Plains Field Station, Breeza managed by NSW Agriculture. The study of changes in soil C fractions and soil physical fertility at the long-term trial at Breeza was complemented by a survey of commercial farming paddocks located on the Liverpool Plains in northern NSW. All the soils in the survey were black vertisol soils similar to the long-term trial site with an uncropped reference site located nearby. The final component of this study was a glasshouse-experiment using dual-isotope labelling with ^{13}C and ^{14}C to measure changes in soil carbon (C) due to residue

decomposition and inputs from the growing crop. The influence of tillage and the type of crop residue were also investigated in this study.

The use of the $KMnO_4$ fractionation technique showed that cropping has resulted in large declines in the labile soil C fraction. Tillage management did not result in consistent changes in soil C fractions at the field trials. Tillage had no effect on soil C fractions at the Breeza site while it was shown that no-tillage practises at Croppa Ck resulted in a 21 and 14% higher concentration of labile C compared to stubble-mulching and stubble-burning, respectively.

Crop rotation and fallowing caused substantial losses of soil C. Long-fallowing caused a 16% decline in labile soil C and resulted in the CMI falling from 89 to 64. Prior to fallowing the carbon management index in a fababean-wheat rotation was 87 compared to 66 for continuous cereal. This improvement though was lost after the fallow period, with the CMI declining to 63 and 65 in both rotations, respectively.

Cropping caused a decline in soil physical fertility at the Breeza site. Infiltration through macropores fell by 63% in cropped areas compared to the reference site. Cropping also resulted in a 55% decrease in water aggregate stability with a decline in the proportion of aggregates >250 μm and an increase in those <125 μm.

Seasonal variations in soil carbon fractions were studied using monthly samples taken from the long-term tillage trial at Breeza. The seasonal changes in soil C fractions were compared to nitrogen mineralisation data that had been determined in a previous project. There were some similarities between the fluctuations in soil C fractions and nitrogen mineralisation but no significant relationship was found. Environmental factors, particularly rainfall, appeared to be the main drivers of these seasonal changes.

The soil survey of cropping paddocks on the Liverpool Plains showed substantial losses of labile soil C fractions compared to the uncropped reference sites. Cropping caused an average 54% decline in labile C compared to the reference sites resulting in an average CMI of 44. The loss of soil physical fertility in the cropped areas was reflected by a 69% reduction in water stable aggregates and a 60-80% reduction in unsaturated hydraulic conductivity. Minimum-till tended to reduce the losses in infiltration, especially when large amounts of crop residues were present. Results from the survey and trial data showed a strong relationship between soil C fractions and soil physical fertility. Other studies that have investigated the role of organic matter and soil C in vertisol soils have found varied relationships between these aspects of soil fertility.

The influence of plant residue quality and tillage management on soil C fractions was further investigated in a glasshouse experiment using a dual-isotope labelling technique. Residues of medic (*Medicago truncatula*), Flemingia (*Flemingia macrophylla*) and rice (*Oryza sativa*) labelled with $^{14}CO_2$ were either incorporated or allowed to decompose on the soil surface while growing wheat plants were labelled with $^{13}CO_2$. This allowed a measurement of the direct contribution of C from the growing crop through roots and root exudates to be determined while the residue-derived C could also be studied.

Residue type was found to be an important determinant of changes in soil C fractions. The incorporation of residues resulted in a 59% recovery of the C added in residues in the soil compared to only 41% when applied to the soil surface, as in no-till systems. The contribution from the growing crop in the form of both coarse and fine roots, and also from root exudates was equivalent to 2718 kg C/ha. This direct contribution from the roots plays an important role in improving the soil C concentration in no-till farming systems.

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