Effect of tree belt plantings on nematode communities in pastoral farming systems

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Abstract
By focussing on the central role of the soil –dwelling nematode community in pastoral farming systems of the New England bioregion in Australia, this study aims to discover how restoring native vegetation to farming systems, in the form of diverse, native tree belt plantings, may enhance soil biodiversity and functioning within adjacent pastures. It is hypothesised: 1) that landscape scale patterns of diversity and function of nematode taxa in pastoral farming systems increases as a direct response to native tree-belt plantings, 2) that the local scale distribution of nematode taxa and functional groups are nonlinearly related to distance, as a function of tree heights, from the tree-belt, and 3) that microclimatic conditions and habitat and resource heterogeneity created by tree-belts are major drivers of nematode diversity and function in these systems. Spatial analysis of variables include: nematode abundance, functional groups and genera, plant species diversity and tree belt structure, litter quantity and quality, soil moisture and temperature fluxes, carbon, porosity, ammonium/nitrates, and pH. A spatial sampling method, based on pilot study findings, will be presented, along with results from the first round of sampling conducted in summer of 2009/2010. It is expected the model developed will provide design rules-of-thumbs to land managers.

Key Words
Shelter belts, ecology, holistic, land use, resilience, climate change

Introduction
Conversion of native vegetation for agriculture continues to threaten biodiversity globally. The impact of this on soil biodiversity, however, is largely unexplored or quantified. Yet biodiversity is recognised worldwide as a key driver of adaptive capacity and ecosystem resilience, critical in the face of global climate change. These points raise an important agro-ecological question; by integrating above-ground native vegetation into farm systems to address declining above ground biodiversity, can we enhance soil biodiversity and functioning that underpins farm fertility and productivity?

A method for restoring native vegetation to farming systems is tree belt plantings. In Australia, tree belt aerodynamic properties have been shown to consistently benefit microclimate, soil abiotic properties and productivity despite different regions and management strategies (see McKeon *et al.* 2008). Generally, tree belts have been shown to: provide shade/shelter for animal production (Bird *et al.* 1993); decrease wind erosion, reduce evaporative losses, buffer microclimate extremes, reduce physical damage to plants (Bird *et al.* 2007; Cleugh 2003; McKeon *et al.* 2008); provide habitat for biodiversity (Dengate 1983); control water-logging and dryland salinity (Ellis *et al.* 2006; White *et al.* 2000); increase organic matter and trap sediment and water, including gains on incidental rainfall, within belts (Ellis *et al.* 2006; Leguedois *et al.* 2008; White *et al.* 2000); and increase soil moisture and pasture/crop production in the quiet zone, an area up to six tree heights on the lee side of tree belts (Figure 1) (Bennell and Verbyla 2008). Fencing so that tree/shrub litter can accumulate within the tree belt in the absence of stock, is an important design factor for effective run off capture, moisture rentention, plant biodiversity and habitat creation (McKeon *et al.* 2008)

Tree belts are therefore a valuable tool for mitigating local scale effects of global climate change. For example, in Australia, where it is expected farmers will generally experience reduced rainfall and more extreme temperatures, tree belts provide a tool for buffering climate extremes while increasing water retention in a drying landscape and providing an opportunity for carbon capture in soils and vegetation as a result of the land use change (Ellis *et al.* 2006; McKeon *et al.* 2008).

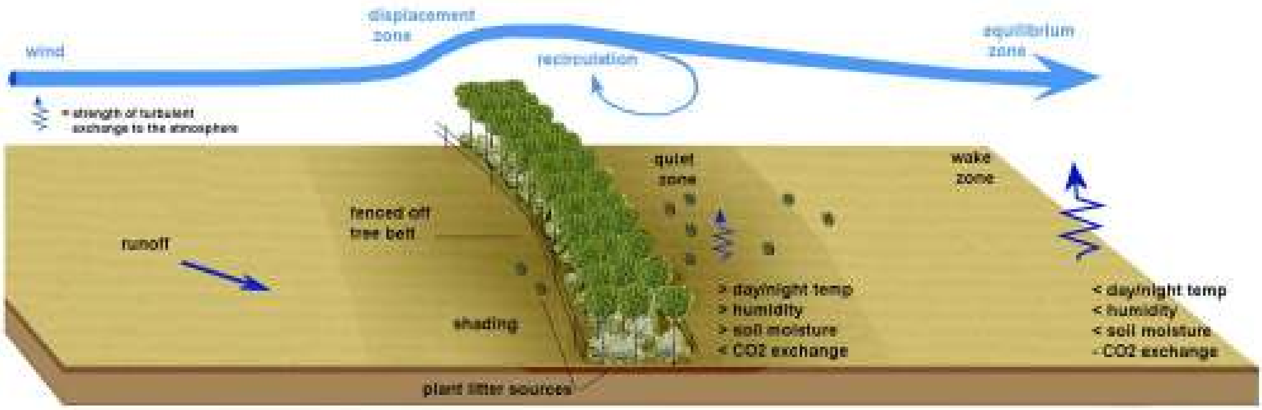

Figure 1. A conceptual model of tree belt effects in agricultural farm systems. Litter accumulates within the tree belts and in areas adjacent. Diverse plantings increase diversity in soil food resources, which may affect soil biodiversity and function. Other factors include changes to soil temperature and moisture, changes to productivity in the quiet zone (reduced wind speeds, shading and reduced turbulent exchange to the atmosphere) compared with the wake zone (where turbulence and wind speed levels return to the same as the wind above), and feedbacks to soil structure and chemical fertility.

What is absent from the general literature is tree belt effects on soil biodiversity and function. Embedded within the aim of this study is to discover if a similar generalisation to those above can be applied. Generally, soil biological function and diversity is influenced by food resource availability and diversity, changes in soil structure, temperature and moisture, as well as the chemical environment (Bardgett 2005). It is plausible therefore that soil biota may respond, within a nominal distance (number of tree heights) of the tree belts, to increased litter inputs, shading, reduced wind speeds and reduced turbulent exchange to the atmosphere (Fyfe *et al.* 2008; Wasilewska 2004).

To gain an accurate snapshot of soil health and biological diversity in tree belt pastoral systems, the central role of soil –dwelling nematodes, as soil function and biodiversity indicator, as well as source of plant pathogens, will be explored through spatially comprehensive, taxonomic analysis of nematode functional groups and genera, following Yeates (2003), Yeates and Bongers (1999) and Yeates and Stirling (2008). The aim being to discover how these native tree-belt plantings increase nematode diversity and function across multiple scales in Australian grazing landscapes and facilitate soil agro-ecosystem fertility.

It is hypothesised; 1) that landscape scale patterns of diversity and function of nematode taxa in pastoral farming systems increases as a direct response to native tree-belt plantings, 2) that the local scale distribution of nematode taxa and functional groups are nonlinearly related to distance, as a function of tree heights, from the tree-belt, 3) that microclimatic conditions and habitat and resource heterogeneity created by tree-belts are major drivers of nematode diversity and function in these systems.

It is expected that the project will develop design rules-of-thumb for land managers by quantifying native tree-belt effects on the productivity and resilience of pastoral farming systems through stimulation and protection of soil biodiversity, as indicated by nematode community ecology.

Methods and results

Study area

Field sites are located on three properties in NSW, Australia, on the wool/sheep production areas of the New England Tablelands. Three tree belts, each planted between 1994 and 1999 (10-15 years old) have been selected for the project. They predominantly consist of tree, shrub and grass species endemic to the area, are structurally complex (tree and shrub layers) and fenced to exclude stock allowing development of ground covers and a litter layer. Sites will be sampled biannually for two years.

Sampling

The sampling strategy will be based on results from a pilot study conducted late 2009, where spatially intensive sampling for nematode taxa and functional groups within and adjacent to two tree belts at one property has been conducted (Figure 2). The results presented will be for the spatial sampling method developed from this pilot study, and from the first round of sampling conducted in summer of 2009/2010.

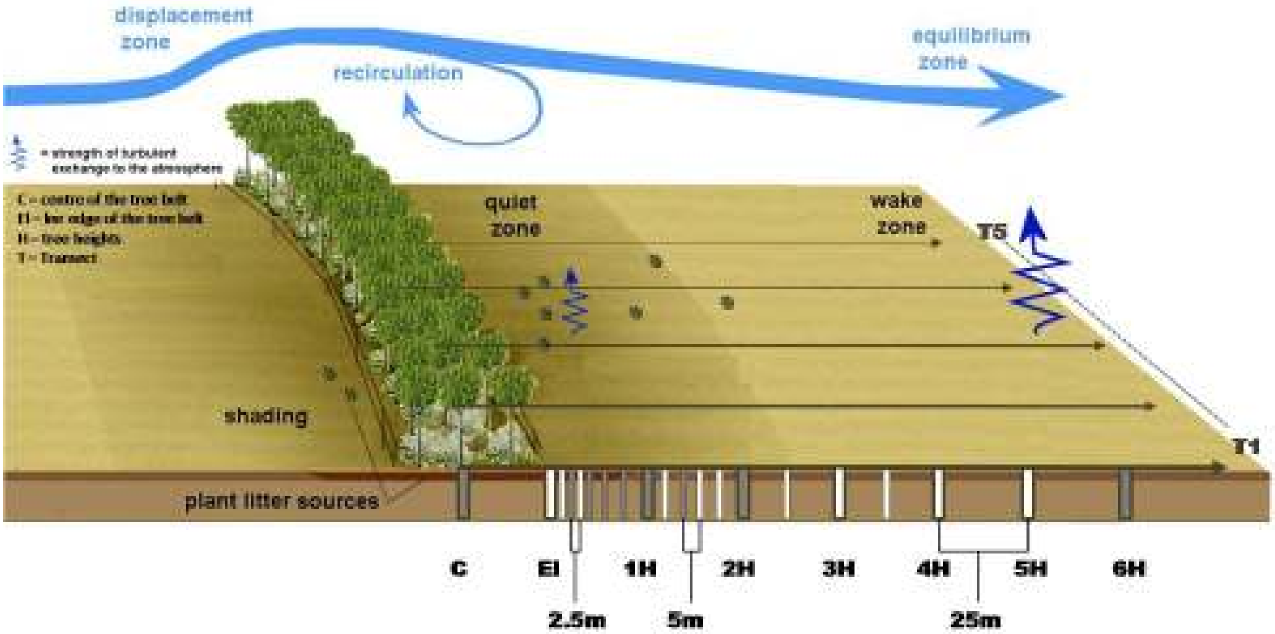

Figure 2. Pilot study sampling strategy conducted at 'Nant Lodge' near Glen Inness, NSW. Spatial variation in nematode abundance, functional groups and genera will inform the sampling strategy for the following two years of biannual sampling. Five transects on the lee side of one tree belt were sampled at all intervals indicated, from the centre of the tree belt (C) out to six tree heights (6H), a distance of 150m. More intensive sampling was conducted within the area more likely to be influenced by tree belt litter. At a second replicate tree belt, three transects where sampled at points indicated by grey shading.

Sampling in 2009/2010 will include soil biological, physical and chemical characteristics, as well as above ground vegetation diversity, quality and structure. At each sampling point, nematode abundance, functional groups and genera will be analysed as the response variables. Explanatory variables include: plant species diversity, function and dominance; tree belt structure (optical porosity, tree height and shrub height) and configuration (width, aspect, on contour, down/across slope); percent ground cover; litter quantity (depth) and quality (C:N); *insitu* logging of soil moisture and temperature to establish daily fluxes; soil carbon (total, organic and labile), soil bulk density and porosity; changes in ammonium/nitrates, and pH. Three further rounds of sampling will be conducted in winter 2010, summer 2011 and winter 2011. Results from the first two rounds of sampling will inform field trials that manipulate certain variables identified by analysis and modelling. Assessing the location of the tree belt root zone may also be considered during this time.

Statistical analysis and modelling

Explanatory variables will be tested for colinearity in the first instance using Spearman's rank correlations and from which explanatory variables for univariate (e.g. ANOVA) and multivariate analysis (e.g. hierarchical partitioning), and mixed effects models (e.g. GLM) will be assembled and analysed using 'R' (R Project for Statistical Computing release 1.9.0 http://www.r-project.org).

This project will develop a predictive model from the study sites within the New England Region to be tested both locally and within different regions, e.g. the higher rainfall Dorrigo plateau to the east, and the lower rainfall Liverpool plains to the west, to ascertain if patterns are spatially consistent for different types of agro-ecosystems.

Conclusion

This study in soil spatial ecology is cross disciplinary, bringing together botany, zoology, geography and spatial ecology, while being rooted in soil science. It examines relationships between above and below ground diversity, what controls biodiversity belowground (at local and landscape scales), and how this affects the function of the system of interest; themes identified by the National Academy of Frontiers in Soil Science (Steering Committee for Frontiers in Soil Science Research and National Research Council 2009).

Tree belts provide a tool for buffering climate extremes while increasing water retention in a drying landscape and providing an opportunity for carbon capture in soils and vegetation as a result of the land use change. This project will address a gap in the literature regarding tree belt effects on soil biodiversity and function and will develop design rules-of-thumb for land managers by quantifying how native tree-belts may stimulate and protect soil biodiversity, as indicated by nematode community ecology.

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